HIGH FREQUENCY CURRENTS.

HIGH FREQUENCY CURRENTS;

Their Production, Physical Properties, Physiological Effects, and Therapeutical Uses.

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LONDON

BAILLIÈRE, TINDALL AND COX

8, HENRIETTA STREET, COVENT GARDEN

1906

PREFACE.

In submitting this book to the English-speaking members of the medical profession, the author hopes that it may in some way help to bring before the notice of medical men the undoubted therapeutical value of high frequency currents in certain pathological conditions.

On the Continent, and in the United States of America, the efficacy of the currents is well known, and much good work has been accomplished by their means; but in England, it would appear, they have not met with the recognition they deserve, possibly because they unfortunately have, in many instances, fallen into the hands of irresponsible, unqualified persons.

It cannot be too strongly insisted upon that the prescribing and administration of high frequency currents should be placed entirely in the hands of properly qualified medical practitioners, and not entrusted to others who may be devoid of any physiological or pathological knowledge. It stands to reason that a powerful agent, having far-reaching physiological effects, requires as much skill and discretion in its use as the exhibition of any drug in the Pharmacopœia.

It remains for the author to express a sense of deep gratitude to Mr. Clarence A. Wright, who has most kindly allowed him free access to many of his manuscripts; to Mr. Geoffrey Pearce, who has been of great assistance in matters relating to instrumentation; and to various instrument makers who have kindly lent "blocks" for some of the illustrations.

H. E. C.

IVERMORE,
RICHMOND ROAD,
TWICKENHAM.
September, 1906.

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PART I.

THE PRODUCTION AND PHYSICAL PROPERTIES OF HIGH FREQUENCY CURRENTS.

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CHAPTER I.

THE HISTORY OF HIGH FREQUENCY CURRENTS.

High frequency currents may be defined as electric currents of a very high potential having oscillations of enormous frequency.

Professor Joseph Henry, of Washington, was the first to point out that the discharge from a Leyden jar is oscillatory in character.

If a charged condenser or a Leyden jar be discharged through a conductor of high resistance, the discharge increases in strength at first and then gradually dies away. If, however, the condenser be discharged through a conductor of low resistance, the discharge consists of a number of exceedingly rapid oscillations or surgings. This is caused by the self-induction of the circuit, by reason of which the current once set up tends to go on. The first rush more than empties the condenser, and charges it the opposite way; then follows a reverse discharge, which also overdoes the discharge, and charges the condenser the same way as at first, and so on.

Each successive oscillation is less than the preceding one, so that after a number of oscillations the discharge dies away.

Lord Kelvin, in 1853, showed that if

C be the capacity of the condenser,
R the resistance, and
L the co-efficient of self-induction, then if

R be greater than $\sqrt{\frac{4\,L}{C}}$ the discharge is continuous, but if

R be less than $\sqrt{\frac{4\,L}{C}}$ the discharge is oscillatory.

In 1865 Maxwell put forward the electro-magnetic theory of light, which is that waves of light are not merely mechanical motions of the ether, but that they are electrical undulations. This theory, at the time, was without any experimental basis, but in 1888 Hertz succeeded in establishing the fact of a propagation of electric waves obeying the laws presented by Maxwell. Hertz employed to set up the waves an apparatus called an oscillator, consisting of two metal balls (A) insulated from each other, but nearly united by a metal rod, in the middle of which was interposed a spark-gap comprised of two metal knobs (B) with an intervening space.

The oscillator was connected with an induction coil (C). When a spark passes across the gap it sets up a temporary conducting path for the surgings to follow. Each spark set up by the coil across the gap consists of a number of oscillations, each lasting about $\frac{1}{100,000,000}$ of a second, the period being determined by the capacity and self-induction of the apparatus.

The study of these oscillations has occupied the attention of a great number of scientists, but as regards the

production, the study, and the utilization of high frequency currents we are mostly indebted to Hertz, Tesla, Thomson, and D'Arsonval.

In 1889 Joubert, using the apparatus of Hertz, previously described, found that the galvanoscopic foot of a frog did not respond to currents having an enormous number of oscillations per second.

In 1890 D'Arsonval showed that currents having a very high number of oscillations per second did not have any effect on either motor or sensory nerves.

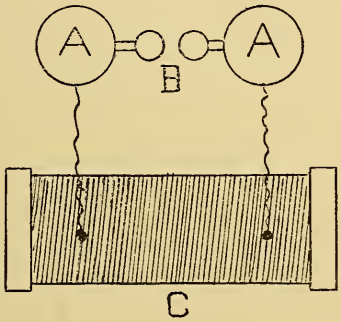

FIG. 1.—HERTZ' OSCILLATOR.

In 1891 Tesla demonstrated to the American Institute of Electrical Engineers his experiments on high frequency currents; while devoting himself more particularly to the problems of electric lighting, and making use of the discharge from condensers, thus obtaining a very high frequency of alternations and a voltage equally high, he came to the same conclusions as D'Arsonval as to the physiological effects of the currents.

It was about this time that Elihu Thomson, using the discharge from condensers, greatly contributed to the

simplification of the means of producing high frequency currents.

D'Arsonval then devised an apparatus which was suggested to him by the experiments of Sir Oliver Lodge on lightning conductors; he connected the internal armatures of two Leyden jars with the terminals of the secondary circuit of an induction coil; the external armatures were connected to one another by means of a spiral composed of about fifteen to twenty turns of a thick copper wire (the solenoid). To each internal armature a metal rod was attached terminating in a ball so placed as to form a spark-gap; each time a spark crossed the spark-gap a current of a very high potential and a very high frequency of oscillations was set up in the solenoid, and could be collected from its two ends.

From this time D'Arsonval paid more attention to the therapeutical value of high frequency currents than to their physiological effects. Professor Bergonié, in his report to the Brussels Congress, states: "There is a name which will constantly be brought to our notice, but not so often as it deserves, in connection with this subject which would not exist if it were not for his work; it is that of Professor D'Arsonval, of the Institute of France. He has one after the other invented the necessary instruments for producing high frequency currents; he has formulated their physiological effects, and amply demonstrated their application in electro-therapeutics."

CHAPTER II.

SOURCES OF ELECTRICAL ENERGY.

In order to produce high frequency currents it is first necessary to consider from what source the electrical current is to be obtained, and secondly, how it is to be changed in character so as to enable it to be used to charge a condenser as described in Chapter I.

Electric-light mains may be used for this purpose, whether they are continuous or alternating, and are certainly the most convenient.

It is not possible, however, to obtain a main supply of electrical current everywhere, and under these circumstances either primary or secondary batteries must be used.

In the early days of electro-medical work primary batteries were employed, but by reason of the trouble they entail, their cumbersome size, the corrosive liquids they contain, the attention they need, their liability to breakage, and their small capacity, they have been practically abandoned. They are, however, useful where there is absolutely no other means of obtaining an electrical supply.

It is interesting to mention the construction and action of a primary battery. This consists essentially of two

electrodes of dissimilar materials, immersed in a conducting solution of such a nature that chemical changes take place when the electrodes are so connected that an electrical current can pass through one to the other. In the bichromate cell a plate of zinc is one pole (the anode), while a pair of carbon plates, one on each side of the zinc and joined together at the top, constitutes the other pole (the

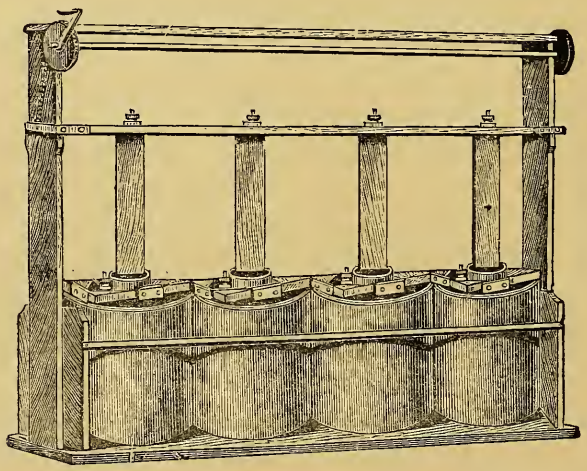

FIG. 2.—PRIMARY BATTERY.

cathode); these are immersed in a solution of sulphuric acid to which is added bichromate of potash, which acts as a depolarizer. This cell gives an electromotive force of about 2 volts.

The secondary battery cell consists of two plates of lead immersed in diluted sulphuric acid; the acid should have a specific gravity of 1·15 to 1·20. The sulphuric acid causes a thin layer of sulphate of lead to form on the plates; if

an electric current be sent through the cell, the sulphate of lead connected with the positive pole is changed to peroxide of lead, and bubbles of oxygen form, while the sulphate deposited on the plate connected with the negative pole is converted into spongy metallic lead, and hydrogen appears in bubbles.

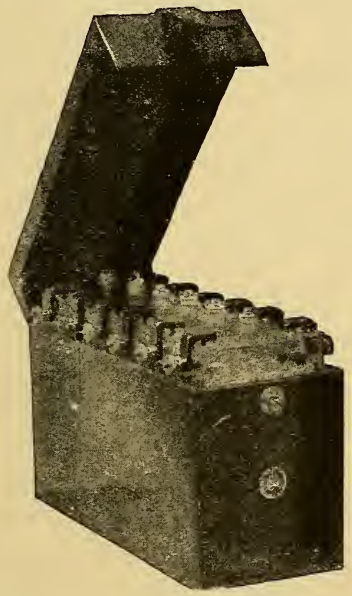

FIG. 3.—PORTABLE ACCUMULATOR (SECONDARY BATTERY).

When the bubbles of oxygen and hydrogen rise to the surface and make the solution milky, the accumulator may be considered to be fully charged. If now the plates are connected to a conductor, an electric current will flow in the opposite direction to the current which previously charged the cell, and when the current ceases the plates will be found to have returned to their original condition.

This process of charging and discharging may be repeated indefinitely.

It will be seen that the difference between primary and secondary batteries is that the former are charged by chemicals which have to be renewed when the cell is exhausted, while in the latter the current generates the chemicals, and when the cell is exhausted, or nearly so, the current will again regenerate the cell without any renewal of acid.

Continuous-current mains may be used to recharge accumulators, the current being passed first through a

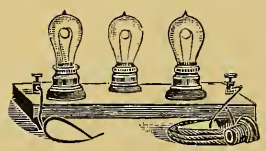

FIG. 4.—LAMP-RESISTANCE CHARGING-BOARD.

number of lamps which serve as a resistance to control the current being passed into the accumulators. Great care must be taken that the main is connected in such a way that the current flows through the lamps to the positive pole of the accumulator, through the cells, and then out by the negative pole back to the main.

It will generally be found that when the cell has just been charged it will have an electromotive force of 2 to 2·5 volts; when the voltage falls below 1·8 volts the cell should be at once recharged.

If an accumulator be not in constant use it should still be recharged from time to time and thus kept in working

order, as if it be allowed to run down sulphate of lead in a crystalline form is liable to be deposited on the plates, and this insoluble salt will so increase the internal resistance and decrease the storage capacity that the cells will be ruined.

An accumulator of ordinary size consists of 3 to 6 cells, giving a total pressure of from 6 to 12 volts, according to the number of cells.

Accumulators are now made in a very much more portable form than hitherto, which is an important consideration when they have to be taken any distance to be charged. The advent of the motor-car and the need for portable cells has produced this, and it is now possible to obtain from many of the leading accumulator-makers a very neat and compact form of accumulator, the plates being enclosed in a transparent celluloid cell. By this arrangement there is no danger of the acid being spilt, and the plates may be examined during the process of recharging.

Great care should be exercised in selecting accumulators, and only reliable and well-known makers should be dealt with. The Electrical Power Storage Company make a most convenient and efficient portable accumulator.

If it be not possible to have the accumulators charged at a generating station, a small gas or oil engine is necessary in order to drive a dynamo which will produce an electrical current for the purpose of charging the accumulators.

Where there are electric-light mains in the neighbourhood a supply of electricity can be obtained direct. There

are two kinds of electric current supplied by corporations and companies for public consumption—one is the direct or continuous current, the other is the indirect or alternating current. When currents from the main are employed, it is necessary to know whether the current is continuous or alternating, what the voltage is, and, should the current be alternating, the periodicity or frequency of the alternations.

The difference between the direct or continuous current, and the indirect or alternating current, is that in the former the flow of current is always in one direction and practically at a uniform voltage or pressure, while in the latter the current flows first in one direction and then in the other, with a constant change of polarity, and rises and falls in pressure from maximum to minimum, the alternations or cycles varying from 40 to 100 per second.

The direct-current mains have a voltage varying from 100 volts and upwards. A pressure of 100 volts is the most suitable for ordinary purposes, but of late the electric supply companies have increased their pressure to from 200 to 250 volts, in order to enable the conductors to carry more energy without the necessity of increasing their sectional area, thus saving a considerable amount of capital outlay on copper for the mains.

CHAPTER III.

THE INDUCTION COIL.

An electrical supply obtained either from the electric-light main or from accumulators is of comparatively low tension or voltage (the terms are synonymous), and before it can be utilized for the production of high frequency currents the ratio between pressure and current must be altered.

There are several methods of accomplishing this according to the local conditions and facilities. One way of effecting this transformation is by means of an instrument known as the induction coil, which is applicable principally for use in conjunction with continuous-current mains or with accumulators. It is generally known that when an electrical current is passed through a wire wound round a bar of soft iron the latter is magnetized, and when the current is broken demagnetization immediately results.

This is one of the fundamental principles of an induction coil which consists essentially of four parts—namely, the core (A), the primary winding (B), secondary (C), and condenser (E).

The core in an induction coil represents the iron bar, and the wire wound round it the primary.

The core of an induction coil, however, does not consist of a bar of iron, but of a number of strips of soft iron of good quality carefully annealed and bound tightly together with paraffin tape. Strips of soft iron are used in preference to a bar, as demagnetization is more spontaneous in the former, due to the absence of hysteresis and Foucault currents.

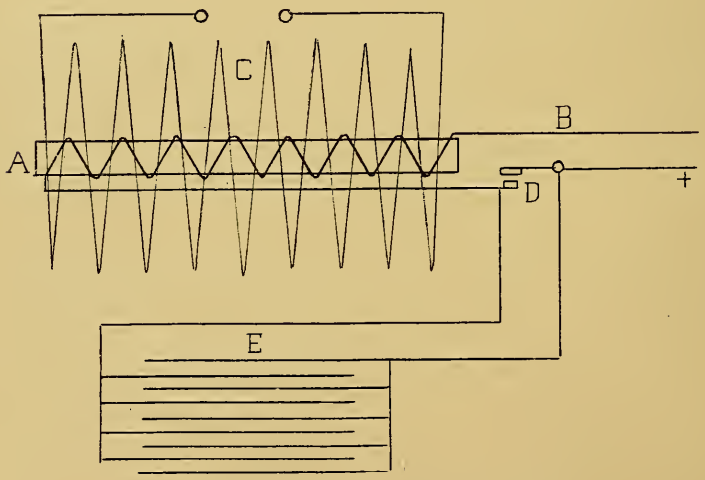

FIG. 5.—DIAGRAM OF AN INDUCTION COIL.

On the outside of the core the primary is wound, consisting of several layers of insulated wire of high conductivity.

In the latest types of coils the primary is subdivided and arranged so that the different layers may be connected in series, series parallel, or parallel, according to

the character of electrical current and the method used to break the current in the primary. The core and primary are both enclosed in a stout ebonite or mica tube.

On the outside of the primary, but insulated from it, is wound the secondary, which consists of a great number of turns of fine wire carefully insulated. The quantity of wire used to form a secondary varies according to the size of the coil, but it may be of interest to note that a coil of such a size as to produce a 10-inch spark requires about twenty miles of wire.

In the older type of coils it was usual to wind the secondary right along the length of the coil; in the improved constructions, however, the secondary is wound in what is known as "multiple section"—that is to say, the wire is wound in a series of wheels or discs, which are placed side by side and separated by a thin sheet of insulating material.

In a coil giving a 10-inch spark there are about seventy to eighty of these sections, the whole being very carefully insulated in paraffin wax and enclosed in an ebonite cover.

Referring to the action of the coil again, the effect of the rapid magnetization and demagnetization of the core is to produce lines of force which circulate round the secondary winding, causing induced currents in the latter which are of very high tension.

Reference has not yet been made to the condenser, the principal function of which is to hasten the elimination of the current from the primary, for much of the efficiency

of the coil depends upon the rapidity at which this is accomplished.

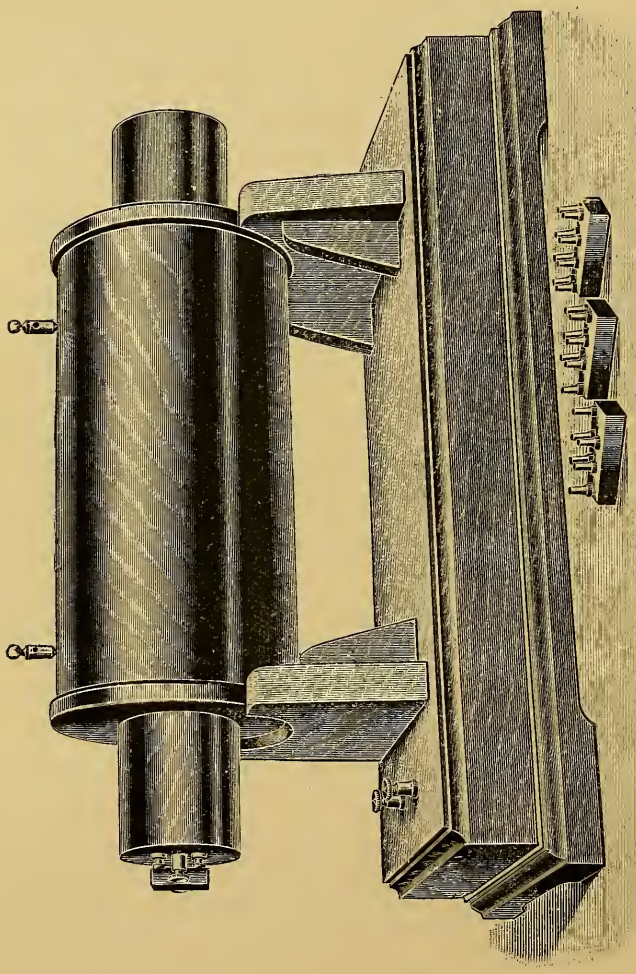

FIG. 6.—INTENSIFIED INDUCTION COIL.

When the current in the primary is broken, the spark at the point of contact is liable to lengthen the time

during which the current can pass, and the process, instead of being a rapid one, is liable to become protracted. The condenser has also the effect of reducing the sparking at the point of contact, as it receives the E.M.F. induced in the primary, caused by the breaking of the circuit.

The condenser consists essentially of a number of sheets

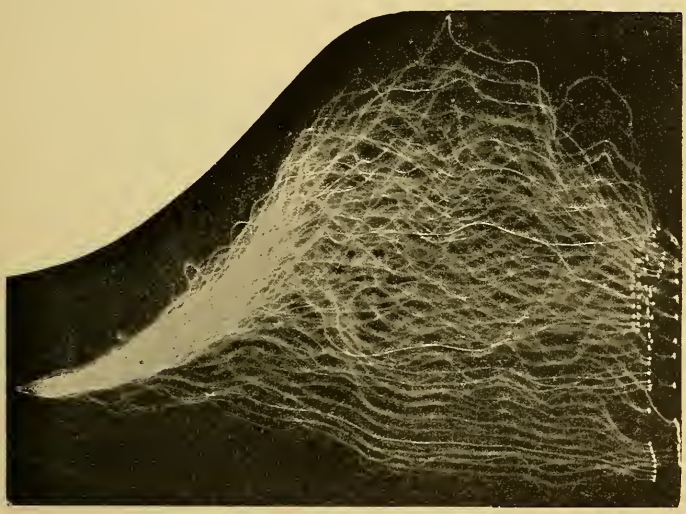

FIG. 7.—SECONDARY DISCHARGE FROM INTENSIFIED INDUCTION COIL.

of tinfoil separated by waxed paper, every alternate sheet of foil being connected together, and the two sets formed in this manner connected to either side of the current interrupter.

A complete coil of the most recent construction is shown in Fig. 6. The tube enclosing the core and primary projects from either end; the large diameter

central portion contains the secondary with the two connecting terminals. The condenser is contained in the base, and the plugs for varying the arrangement of the primary are shown, one in position and three lying in front.

Induction coils are made in various dimensions, their size being gauged by the length of secondary discharge which it is possible to obtain from them. The length of

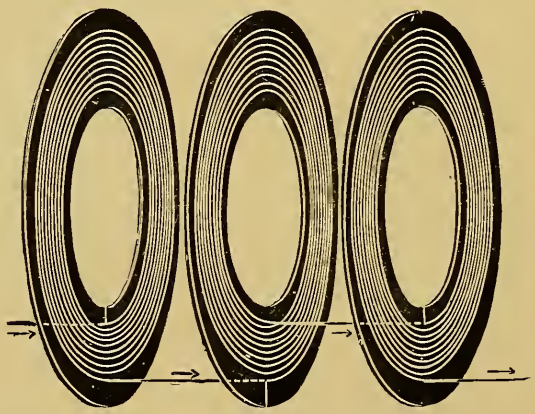

FIG. 8.—DIAGRAM OF JOINTLESS SECTION-WINDING.

the secondary discharge is, of course, proportionate to the size of the primary, secondary winding, etc.

For practical high frequency work a coil capable of producing a secondary discharge of at least 10-inch spark-length is required. Coils giving a much longer spark are advocated by some workers on account of the increased output it is possible to obtain from them. When selecting a coil, consideration must be taken not only of the length of the spark, but of its thickness. A good coil will give

a thick, furry spark which will exceed its nominal spark-length by about 10 per cent.

A new type of induction coil is shown in the illustration on p. 16. This particular coil is known as the Intensified Induction Coil, and the principal advantage claimed for it is the greatly increased capacity of the high-tension impulses compared with other forms of induction coils. This result is obtained by a very careful and exact

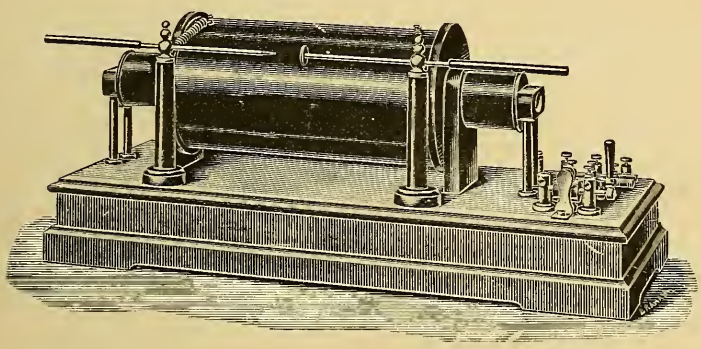

FIG. 9.—INDUCTION COIL WITH SPARKING PILLARS.

measurement of the various qualities of the materials used in its construction. The coil is made only in one size, with the secondary terminals separated by 12 inches, although, so great is the output, it is possible to obtain a discharge varying from 16 to 18 inches in length.

An estimation of the heavy secondary discharge can be gained by Fig. 7, which is an actual photograph of a discharge obtained from one of these coils.

Another good type of induction coil is made on the multi-section principle, but with the sections wound in

one continuous length of wire, without the usual jointing between each section. These coils are designated "jointless section" (Fig. 8), and, on account of the reduced resistance and impedance due to paper insulation instead of the usual wax, produce a heavy secondary discharge.

CHAPTER IV.

CURRENT INTERRUPTERS.

HAVING described the function and construction of the induction coil, the next instrument to consider is that used for interrupting the current in the primary. Too much importance cannot be attached to this instrument, for upon it depends much of the satisfactory working of the apparatus.

The various forms of current interrupters, or contact-breakers, as they are sometimes called, which commend themselves to the worker may be roughly divided into three classes, namely:

The platinum or hammer interrupter.
The motor mercury interrupter.
The electrolytic interrupter.

Describing the different forms of contact-breakers in the above order, the first may be quickly passed over, as it is not altogether adapted for high frequency work. It is one of the oldest forms of current interrupters, probably the oldest, and was used almost universally some years ago, when coils of any size were first used by medical men for the production of high-tension impulses.

The platinum interrupter consists of two platinum points mounted on springs in such a way on the base of the coil facing the core, that when the current is passed they are separated and brought together by magnetic attraction. Fig. 10 shows a diagram of a very good form of one of these interrupters. The effect of passing the

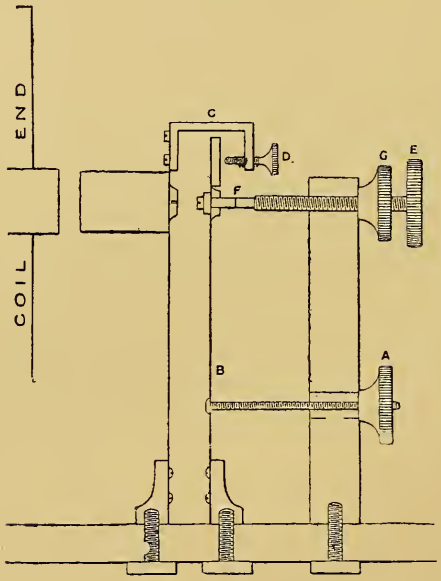

FIG. 10.—PLATINUM INTERRUPTER.

current into the primary is to pull the hammer of the interrupter towards the coil, breaking the circuit between the two platinum points at F. Immediately the current is broken demagnetization of the core results, and the spring carrying the hammer comes back into its original position, when the same process repeats itself.

It will be seen that the speed of make and break is

controlled by means of the adjusting screw D. Tension may be placed on the spring B by means of the milled head A, with the effect that a stronger current is required in the primary to effect a sufficiently strong attraction to separate the platinum points.

On account of the simplicity of the platinum interrupters, and the comparatively small space occupied by them, they are useful in portable apparatus. They are, however, not very suitable, as previously mentioned, for use with high frequency currents, as the speed of interruptions with the majority of forms is not rapid enough, nor is the break sufficiently steady.

Platinum interrupters are best worked from a low pressure of 10 to 16 volts, such as is usually obtained from accumulators.

The motor mercury interrupter for high frequency work is without doubt the most efficient and best all-round contact-breaker. The break consists of two parts—viz., (1) an arrangement for making and breaking the contact between a bath or jet of mercury connected to one pole and a contact connected to the other pole; (2) a motor to supply the power to make and break the current.

It is obvious that by varying the speed of the motor the number of interruptions in the primary circuit can be increased and decreased as desired. The majority of forms of mercury interrupters have the advantage that they will work either from accumulators or from a main supply. There are a number of different forms of mercury interrupters, all of which are more or less efficient.

The mercury jet interrupter, as illustrated in Fig. 11, as its name implies, consists of a jet of mercury which is produced by means of a centrifugal pump, and impinged against wedge-shaped blades revolving at a high speed. The height of the jet of mercury in relation to the blades is adjustable, and by means of this the time and duration of contact can be altered by racking the jet

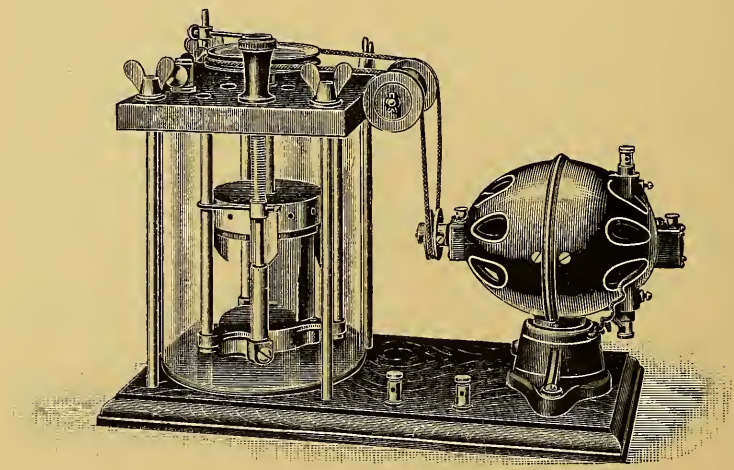

FIG. 11.—TURBINIA JET INTERRUPTER.

up and down. This is of great importance, as with a long period of contact more current can pass than with a short period. In this manner it is possible to adjust to a nicety the quantity of current passing into the primary of the coil, and the consequent effect obtained at the secondary.

The jet interrupter will work equally well on a low voltage (obtained from accumulators), or from high-

pressure electric-light mains, and the currrent which it consumes is comparatively small.

Another advantage with this form of interrupter is that it is impossible for a short circuit to take place in the primary of the coil, as, should the motor inadvertently

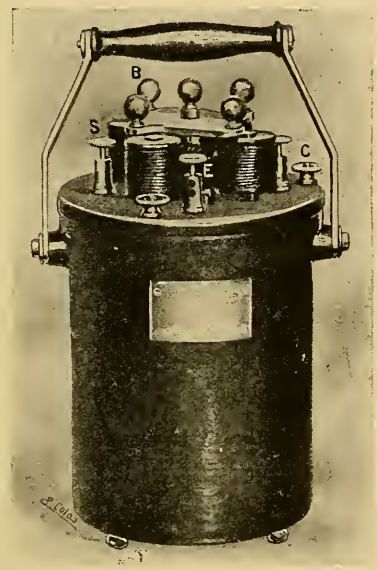

FIG. 12.—AUTONOME INTERRUPTER.

stop with the current connected to the primary, the jet automatically stops as well.

By varying the number of blades, and also the speed of the motor, it is possible to produce practically any rate of interruptions which is required. For high frequency work a rapid interruption of the primary current is essential, and for this particular class of work the jet interrupter has a distinct advantage over other types, as it is possible

to obtain as many as four interruptions per revolution of the motor, whereas with other forms sometimes two, and as a rule only one, interruption is possible.

There is an exceedingly ingenious modification of the jet interrupter which has been recently introduced. A piece of iron of conical form (*d*, Fig. 13) is first channelled by a single canal. This canal is obliquely inclined in relation to the vertical axis in such a way that on rotation the mercury, which when at rest fills the lower half of the canal, is by centrifugal force driven upwards and outwards through the orifice (*o*, Fig. 13) so as to jet against four copper teeth (*a*, Fig. 13), which are insulated from the rest of the apparatus—that is to say, the jet rotates, whilst the teeth are fixed. The width of the copper teeth, as in other interrupters, depends upon the voltage—the higher the voltage the narrower the teeth. The containing vessel is of iron. The quantity of mercury required for this interrupter is 12 pounds.

The driving system is constituted by the direct electrical and mechanical coupling of the motor with the interrupter; the same interruption cuts the current both for the motor and the coil. The motor is of the magnetic attraction type, with fixed winding and rotating armature.

l and l^2 (Fig. 13) are the windings of the motor. P is the armature carrying the palettes p^1 and p^2. The number of poles of the motor is equal to the number of teeth *a* in the crown C, and the armature P is so set that when the jet of mercury makes contact with

one of the teeth *a* the position is that of the maximum magnetic attraction. Interruption takes place a little before the palettes are in position over the core of the electro-magnet.

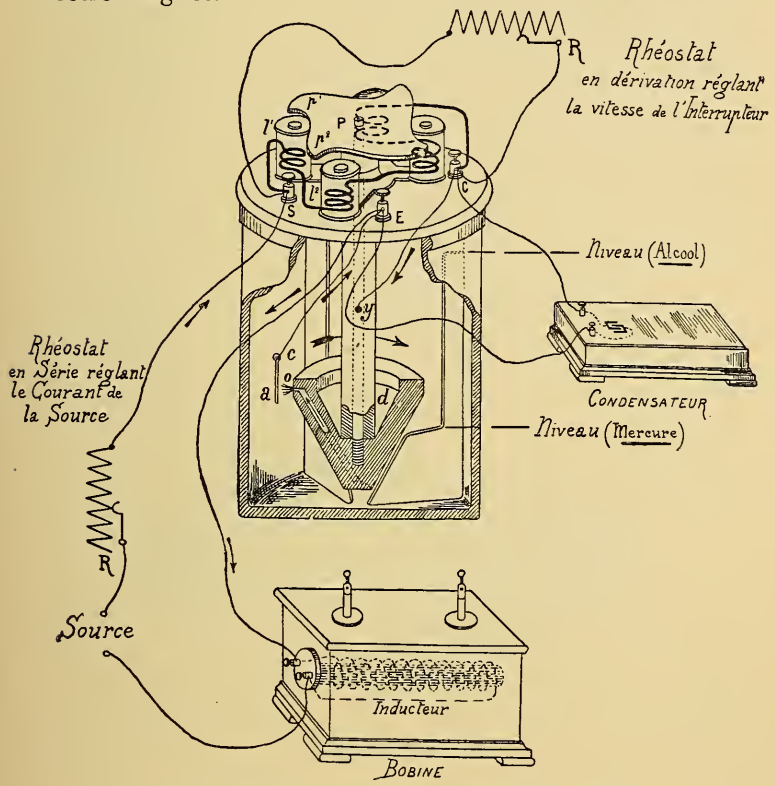

FIG. 13.—DIAGRAM OF AUTONOME INTERRUPTER.

The winding of the electro-magnets is connected in series with the primary winding (*inducteur*, Fig. 13) of the coil. Therefore, to start work the current is turned on, and the armature rotated by a smart impulse with the hands sufficiently vigorous to start the mercury jet.

The current then traverses the primary of the coil, and also the winding of the electro-motor which works automatically.

A modification of the autonome interrupter which will work from an alternating current has just been placed upon the market. The general arrangement of the turbine, etc., is the same as previously described.

A small synchronous motor is fitted on the turbine axle. The windings of this motor are connected in series with the break itself, and a resistance placed in the circuit. A start is given to the motor by the hand, and is continued until synchronism is arrived at. When this point is reached, the motor is switched directly on to the main in order to produce a uniform speed. The only drawback to this ingenious apparatus is the lack of adjustment in the speed of the motor, etc.

There is another form of interrupter, which, however, cannot be strictly called a jet break. This type is constructed very much in the same manner as the turbinia jet interrupter, and consists of a rotating drum in which copper segments are inserted at intervals. A copper brush makes contact against the revolving drum. The brush is perforated and connected with mercury by means of a small tube. The mercury is raised by means of a centrifugal pump through the tube to the brush against the drum. A good contact is thus obtained, which is practically free from friction.

The copper segments are wedge-shaped, as in the jet interrupter, and by altering the position of the brush in relation to these the duration of contact may be

regulated. An advantage of this interrupter is that it only requires about two pounds of mercury.

The interrupter designed by Dr. Mackenzie Davidson is a simple and very efficient contact-breaker, and is used by many workers. It consists of a fan-shaped dipper, which is rotated at an angle of 45 degrees in and out of a bath of mercury which is contained in an iron pot. The shaft carrying the dipper is provided with a

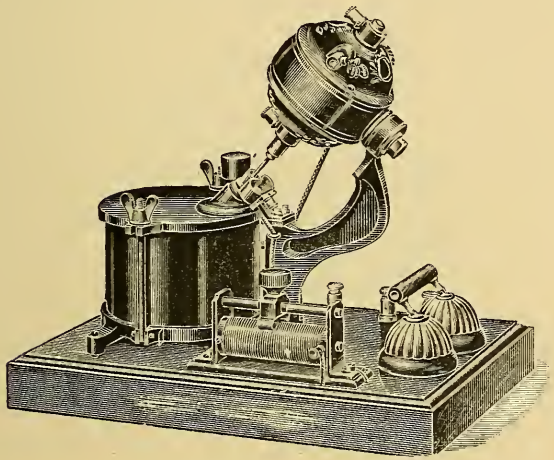

FIG. 14.—MACKENZIE DAVIDSON INTERRUPTER.

small driving-wheel, which is connected to a motor by means of a leather band.

This interrupter is simple in construction, and only requires about 5 to 6 pounds of mercury. The best results are obtained from this break when working from a low voltage (accumulators). A pressure of 24 volts is usually employed, although it may be worked from a main supply if desired.

Another form of mercury interrupter is that known as the dipper interrupter, and consists of a motor on the shaft of which is arranged a crank which drives a dipper in and out of a vessel containing mercury. The only disadvantage of this form of break is its liability to splash the mercury over the apparatus, and cause a general dirty condition, unless the dipping rod enters and leaves the mercury absolutely in the perpendicular.

There is a type of this interrupter which is provided

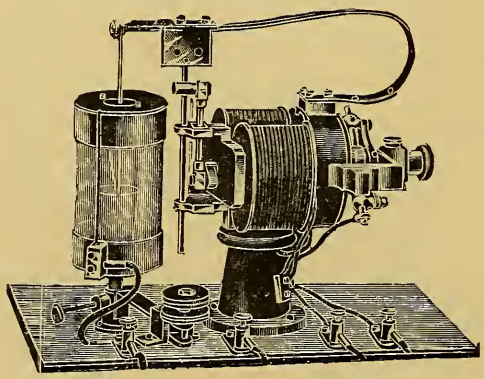

FIG. 15.—DIPPER INTERRUPTER.

with two dippers on a double-throw crank, which alternately dip into the mercury contained in an iron vessel. When the motor is running, and one of the dippers comes into contact with the mercury, the circuit is complete, and allows the current to pass until on the up-stroke of the crank the dipper separates from the mercury and again breaks the circuit. This cycle of operations is repeated with each dipper.

In all mercury interrupters the point of contact has to

be covered either with alcohol or petroleum, in order to reduce the spark. After the break has been running some little time, and the mercury churned up, the liquid, which is used to cover the point of contact, mixes with the globules of mercury and becomes a dirty sludge, which in time impairs the working of the break and necessitates the cleaning of the mercury. This is an unpleasant and dirty process, and is one great drawback to all forms of mercury interrupters.

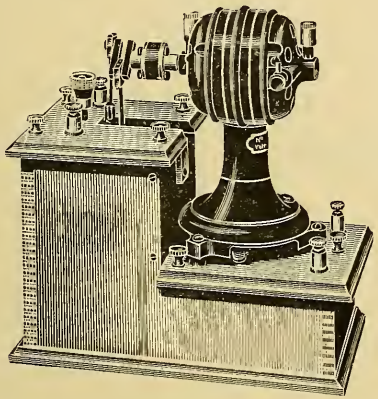

FIG. 16.—DOUBLE-DIPPER INTERRUPTER.

There yet remains the third class of interrupter to describe, which, similar to the first, is not altogether suited for the production of high frequency currents.

There are several different forms of this contact-breaker which act on the principle that if a strong electrical current is passed through an electrolyte by means of two electrodes, one of which has a comparatively small area exposed, the current will be interrupted by the formation of contact gases over the small electrode.

The best-known form of this break is that designed by Dr. Wehnelt, and is illustrated in Fig. 17. The break consists essentially of a glass vessel, suspended in which, in sulphuric acid, is a lead electro of large surface, and a porcelain tube through the bottom of which a platinum

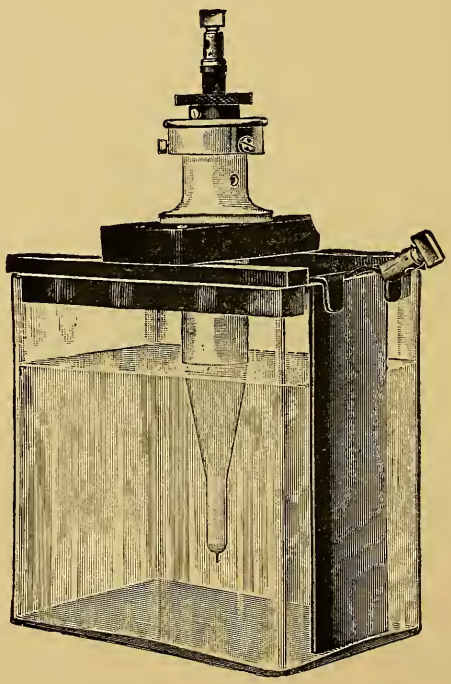

FIG. 17.—WEHNELT INTERRUPTER.

wire projects. The amount of projection below the tube into the liquid may be regulated by means of a milled head on the top, and in this manner it is possible to adjust the break for interruptions of various frequencies, and to compensate for the wear and tear of the platinum.

The disadvantage of this break is that the liquid heats after the break has been running for some little time, and the bubbles of gas do not form freely on the platinum wire; in addition to this, sulphurous acid fumes are generated, which makes it necessary for the break to be kept in some place other than that in which the high frequency apparatus itself is used.

Reference has already been made to resistances for

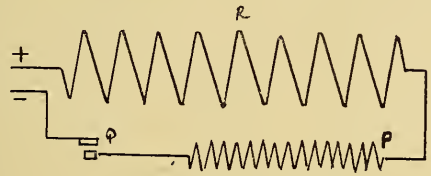

FIG. 18.—SERIES RESISTANCE.

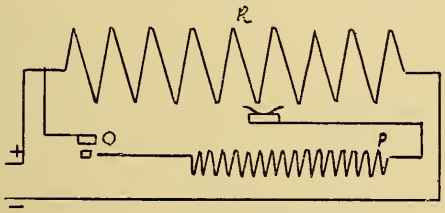

FIG. 18A.—SHUNT RESISTANCE.

insertion between the electric-light main and induction coils, and also to rheostats for controlling the speed of the motors or mercury interrupters.

The resistances or rheostats are usually mounted behind a marble, slate, or wood board, on which the switches and measuring instruments are placed. Resistances for insertion between the primary circuit of a coil and electric-light mains may be divided into two classes—namely, series and shunt.

The former is arranged as shown in Fig. 18—that is to say, the primary of the coil P is in series with the main, and current only flows through the resistance R when the circuit is closed by the interrupter Q.

FIG. 19.—SWITCH AND RESISTANCE BOARD.

The shunt, Fig. 18A, however, is connected directly across the mains, one end of the primary circuit P being attached to one end of the resistance R when Q is closed, whilst the other end is connected to some point along the resistance.

Both forms have their own advantages and disadvan-

tages. The series resistance consumes only that quantity of current which is passed into the primary, and for that reason is economical in use and does not heat to any appreciable extent. It is, however, impossible to measure with this arrangement the actual voltage across the primary terminals.

The shunt resistance is somewhat wasteful as regards current, as it not only consumes that quantity of current which is necessary for the coil, but also a certain amount is absorbed in the resistance itself. It has, however, the advantage that with it one can measure the potential across the primary.

A complete switch-board, as Fig. 19, for use with the mercury interrupter, is usually provided with a lamp for illuminating the board, an ampèremeter for registering the current passing into the primary of the coil, a voltmeter (if a shunt resistance be used) for measuring the potential at the primary, a double starting switch which places the motor in circuit before the coil and cuts off the coil circuit before the motor circuit is broken, safety fuses, a main switch, rheostat handles and studs for regulating the motor and coil resistances, commutator for reversing the direction of flow into the primary, connecting terminals, etc.

Different makers supply switch-boards which vary in some details from that just described, but all are made practically on the same principle.

CHAPTER V.

THE ALTERNATING CURRENT.

We may conveniently divide the method of utilizing the alternating current into three classes :

1. Step-up high-tension transformer.
2. Motor converter.
3. Electrolytic valve.

The high-tension transformer has only come into practical use during the last two or three years. Until this instrument was introduced those who only had the alternating current at their disposal were placed at a great disadvantage, as there was no satisfactory means of transforming the low tension of the mains to high tension. Now, however, the alternating current is, if anything, considered to be more convenient than the continuous current.

By means of the high-tension transformer we are able to convert a low tension to a high tension of 50,000 to 60,000 volts directly, and without an interrupter in the primary circuit, which is an essential in the case of the induction coil.

The high-tension transformer in outward appearance

somewhat resembles an induction coil, although the latter is usually of a lighter build. Fig. 20 illustrates one of these high-tension transformers, which consist essentially of a closed iron circuit with the primary and secondary windings.

The reason why the high-tension transformer has only recently come into general use as a means whereby we

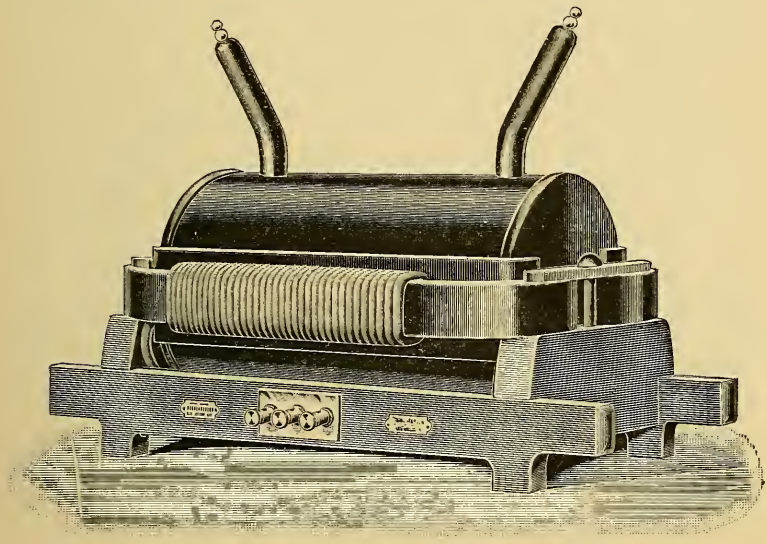

FIG. 20.—HIGH-TENSION TRANSFORMER.

may transform low-tension currents is due to the difficulty there was in producing an instrument sufficiently well insulated to withstand the necessary strain, and the output of which could be satisfactorily controlled.

The nature of an alternating current has been previously explained, and may be regarded practically as an interrupted current, which, being passed into the primary

of the high-tension transformer, magnetizes and demagnetizes the closed iron circuit at a rate controlled by the periodicity of the supply, and causes induced currents of high tension in the secondary.

These high-tension transformers are certainly very convenient, as they require little or no attention, due to the absence of mechanical parts, such as the interrupter, etc. In action they are practically silent, except for a slight hum, and work perfectly steadily.

The great difficulty manufacturers have experienced in making high-tension transformers for high frequency work has been due to the Hertzian waves which emanate from the high frequency circuit, and which are produced in all the conductors which are connected either directly or indirectly with them. The result of this is that the waves, the length of which is considerable, and the tension of which is equal to that produced in the high frequency apparatus, recoil in the high-tension transformer, creating between the neighbouring wires of the winding differences of potential much greater than that for which the transformer has been wound.

If the insulation of the transformer does not resist, short circuits are created, rendering a portion of the wire useless by carrying the dangerous tensions more back towards the centre.

In order to deaden these oscillations various condensers or safety windings are made use of.

For convenience, the various constituent parts of the apparatus are fitted into a cabinet, and the whole installation controlled by means of a suitable switch-board. The

cabinet not only contains the high-tension transformer, but also part of the apparatus necessary for the production of high frequency currents.

With these high-tension transformers it is possible to obtain much stronger high frequency currents than can be produced from the average induction coil.

Some workers who are provided with a supply of continuous current convert it into alternating by means of a motor alternater, as it is considered that the advantage

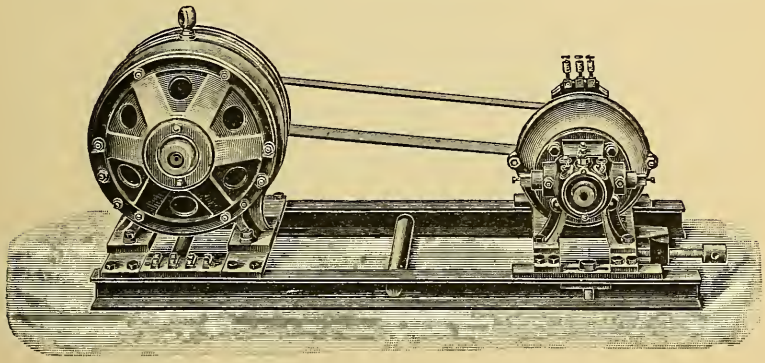

FIG. 21.—ALTERNATING CONTINUOUS MOTOR CONVERTER.

of the high-tension transformer more than repays the additional initial outlay that this necessitates.

The second method of using an alternating current is to convert it into a continuous one by means of an alternating-current motor wound for the particular voltage and periodicity of the alternating mains, which is connected to and drives a continuous-current dynamo. The continuous current may then either be used for the purpose of charging accumulators or directly exciting the primary of an induction coil.

The initial expense of the motor converter is somewhat high, and since the high-tension transformer has been introduced this method of working has almost fallen into abeyance.

The alternating motor and the continuous-current dynamo are usually coupled together on an iron bed-plate, as illustrated in Fig. 21.

The electrolytic valve consists of lead cells containing

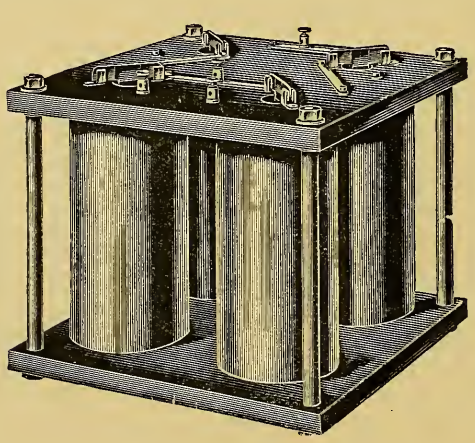

FIG. 22.—NODON VALVE.

a solution of phosphate of ammonium in which aluminium rods are immersed. By this arrangement the alternating current may be used for charging accumulators, driving a motor, and occasionally for working a coil.

One of the best-known forms of this instrument is the Nodon valve, which works on the electrolytic principle.

When the positive phase passes from the aluminium rod through the electrolyte to the lead, a thin insulating

film is formed on the aluminium rod, which prevents the negative phase passing in the opposite direction.

Four cells constitute one of these valves, which are arranged as shown in Fig. 23, the terminals AB being the alternating side, and the terminals CD, when connected, representing the rectified current.

When A is positive the current flows in the direction AEC, and when A is minus the current flows AED. Similarly, when B is positive the current flows BEC,

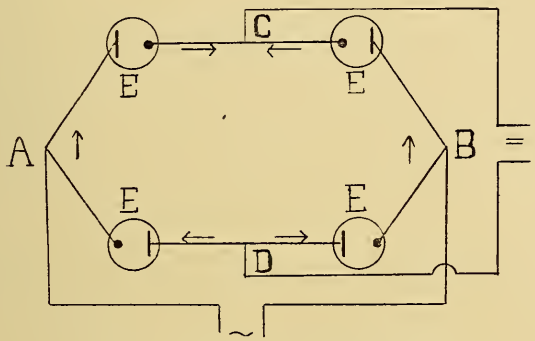

FIG. 23.—DIAGRAM OF NODON VALVE.

and when B is minus the current flows BED—that is, the current flows either AEC, BED, or AED, BEC.

By connecting C and D a unidirectional current is produced—that is, C is always positive and D negative.

The valve will work on a tension of 50 to 140 volts; when higher pressures are to be used either a small motor converter is necessary or two valves are employed.

The efficiency of this valve is claimed to be 70 to 75 per cent.

Rectified current is not, strictly speaking, continuous,

but is a pulsating unidirectional current, and gives excellent results when used for driving continuous-current motors and for charging accumulators, but is not altogether satisfactory for use with induction coils. This is probably due to the fact that the rectified current is pulsating—that is to say, steady pressure, as in the case of true continuous current, is not maintained.

Should the number of interruptions in the primary circuit of the coil synchronize with the pulsations, then the coil will work steadily.

There is one disadvantage in connection with these valve cells, and that is due to heating—in fact, some of the larger forms are provided with fans and motors for circulating a current of air round the cells in order to cool them, and in several forms a water-cooling arrangement has been devised.

Another excellent form of valve is being manufactured by Messrs. Isenthal and Co. In this form special attention is given to free circulation of the electrolyte, and the avoidance of all edges and points. The dimensions are so chosen that very great temporary overloads may safely be put upon the valve. The design of the apparatus is such that no insulators whatsoever are required, and the various sizes are standardized and built up of elementary units.

The starting device also is of such a nature that the conditions of the electrolyte and anodes may always be controlled.

CHAPTER VI.

STATIC MACHINES.

The static machine, in comparison with the induction coil and high-tension transformer, yields a comparatively small output, although the actual tension is very high.

It is, however, interesting to mention the principal construction of a static machine, as it is of value when other sources of electrical energy are not available.

There are various forms of static machines—namely, the Wimshurst, Holtz, Toepler-Holtz, Carré, etc.

The former, however, is the most adapted for high frequency work. It consists of circular glass, mica, or ebonite plates, mounted in pairs in such a way that the plates of each pair can be rotated in opposite directions.

On the outer surfaces of at least one pair of plates are generally fixed strips of tinfoil or brass at equal distances apart. The machine is provided with rods carrying fine wire brushes which press against the plates as they rotate.

Collectors consisting of a series of fine points, which are directed against the rotating discs at an angle of 45 degrees to the brush, are also provided. These points

are supported on efficiently insulated pillars and connected with the discharging rods.

The plates in the smaller types of machine may be rotated by hand or connected to an oil or gas engine, or, if electric current should be available, a motor may be employed.

There are, however, many drawbacks to the Wimshurst

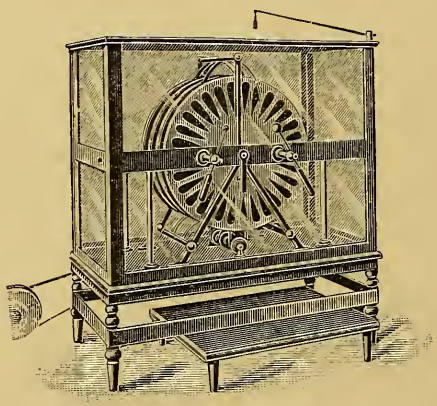

FIG. 24.—GLASS PLATE WIMSHURST MACHINE.

machine, the principal being that the atmospheric conditions, if at all damp, greatly impair its efficiency.

In order to obviate this sensitiveness to damp, glass plate machines are usually enclosed in an air-tight case in which is placed some chemical to absorb the moisture.

Static machines are used to a much greater extent on the Continent and in the United States than they are in England, principally on account of the adverse climatic conditions which we have to contend against.

Ebonite plate machines are not enclosed by air-tight

cases, as the ozone generated in the case would quickly attack the ebonite and render it useless.

The ebonite plate machines have an advantage over the glass plate type, as they may be rotated at a very

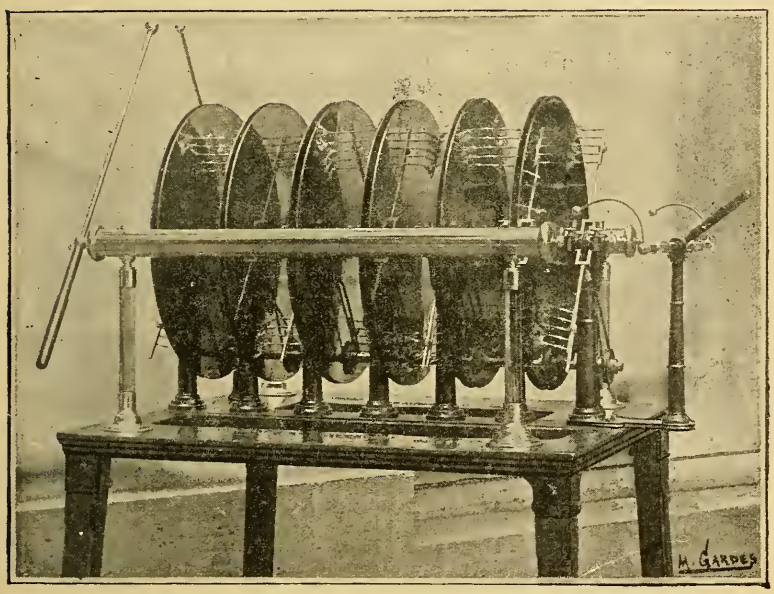

FIG. 25.—EBONITE PLATE WIMSHURST MACHINE.

much higher speed with perfect safety, and consequently a greater output for a given size of plate is obtained.

Glass plate machines as a rule consist of at least eight, and sometimes twelve, plates of 30 to 36 inches in diameter, whereas the usual size of an ebonite plate machine is eight to twelve plates of 24 to 30 inches diameter.

CHAPTER VII.

HIGH FREQUENCY APPARATUS.

VARIOUS instruments for producing high-tension impulses from low tension having been explained in the previous chapters, the next instrument to consider is that for the purpose of actually producing a high frequency current.

There are a number of forms of instrument for producing high frequency currents supplied by various makers, the fundamental principles of which are more or less identical. A complete high frequency apparatus consists of the following: a condenser, spark-gap, solenoid, and resonator.

The general arrangement of these parts is shown in Fig. 26. The secondary discharge from an induction coil, high-tension transformer, or a static machine (A), is connected to the inside coatings of the condenser (C), which are provided with an adjustable spark-gap (B). The outside coatings of the condenser are connected by a coil of copper wire, which constitutes the solenoid (S). The manner in which the high-tension current charges and discharges the condenser with enormous rapidity has already been described in Chapter I.

Oscillations of a frequency equal to the discharge

between the inner coatings of the condenser are imparted to the outer coatings and produced in the solenoid.

The resonator (R) is practically a secondary winding, and

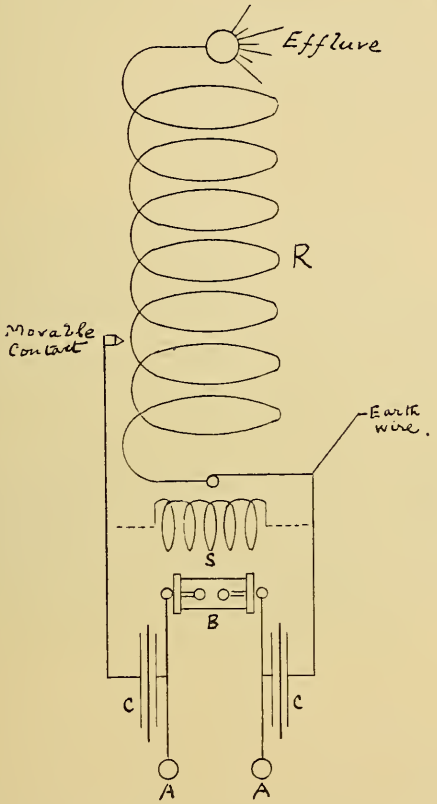

FIG. 26.—DIAGRAM OF HIGH FREQUENCY APPARATUS.

is used to transform the high frequency oscillations to a still higher tension than those obtained from the condenser by a process of self-induction.

Condensers consist either of two Leyden jars or a series

of metal plates separated from one another by an insulating material such as glass.

Leyden jars are a source of continual annoyance and trouble, as the effect of the charging and discharging causes the formation of nitrous acid fumes, which decompose the tinfoil. After the jars have been working some little time the tinfoil powders off, and sparking occurs, which is very disconcerting to both patient and operator, and eventually

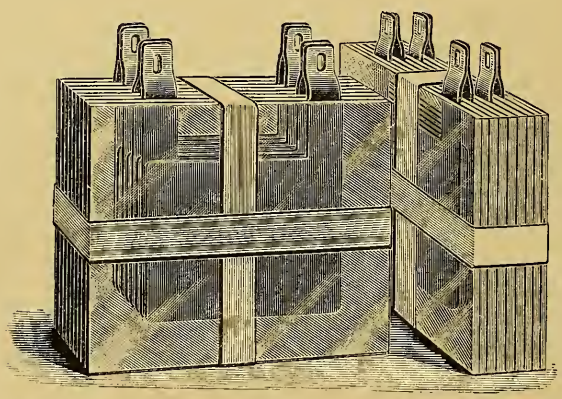

FIG. 27.—GLASS PLATE CONDENSERS.

leads to perforation of the jar. For these reasons the glass plate condenser is very much more satisfactory. Each alternate metal plate is connected together, those on one side forming the outer coatings, and those on the other forming the inner coatings. The glass and metal plates are usually bound together by stout webbing, and attached to a sheet of thick ebonite, from which they are suspended into a containing vessel, and covered with petroleum for the purpose of insulation.

The general arrangement of a glass plate condenser is shown in Fig. 28. It may occasionally happen that one of the glass plates crack through the strain thrown upon it, but it is a comparatively easy matter to replace it with a new one. In this form of condenser there is no deterioration, and results at the end of three months' work are as good as those obtained from the apparatus when

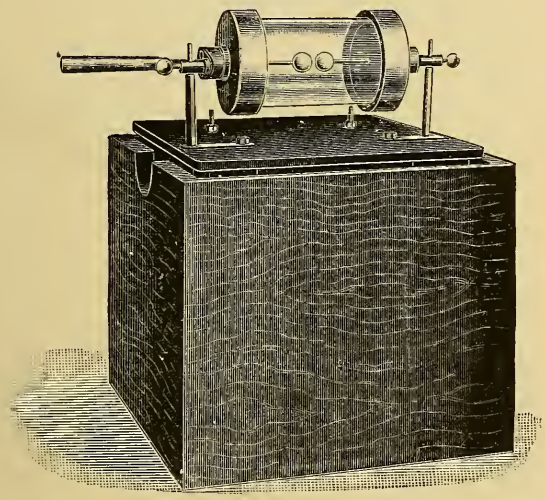

FIG. 28.—HIGH FREQUENCY OIL CONDENSER.

first used. This is not the case with Leyden jars, as naturally, when the capacity of the Leyden jar diminishes as the tinfoil decomposes, the output is decreased.

A new material for separating the metal plates has been recently introduced by Watson and Sons. This substance is made of compressed mica, which is very light, and, on account of its power of resisting the strain thrown upon the insulating portion of the condenser, can be

used in much thinner sheets than if glass plates were employed.

In addition to this, there is no liability to crack, so that the plates may be said to last indefinitely.

The spark-gap is one of the most important parts of a high frequency apparatus. The discharge between the two inner coatings of the condenser, if allowed to take place in air, is deafening, and for this reason the spark-gap is usually enclosed in some form of covering.

The difficulty in connection with all spark-gaps is that nitrous acid forms on the sides of the enclosing arrangement (*vide* p. 59). If this be allowed to collect in any quantity, it forms an alternate path for the current and stops the discharge.

The best forms of spark-gap usually consist of a glass cylinder with ebonite ends, which may be readily detached and the cylinder and sparking balls cleaned after each application. A little French chalk is sometimes placed in the spark-gap in order to absorb the moisture.

Resonators take different forms, and are, as a rule, named after their designers, such as the D'Arsonval, Oudin, etc.

The D'Arsonval resonator is illustrated in Fig. 29, and consists of three or four turns of stout wire, each end of which is connected directly to the outer coatings of the condenser. On the inside of this wire, at a distance of about 1 or 2 inches, is placed a large cylinder of ebonite, on which is wound a number of turns of fine wire. Currents of higher tension than those in the thick turns are induced in the thin wire on the ebonite cylinder, and take the form of an effluve or brush discharge. The

length of this brush can be varied according to the position of the thick turns of wire in relation to the ebonite cylinder.

Another form of resonator is that known as the Oudin,

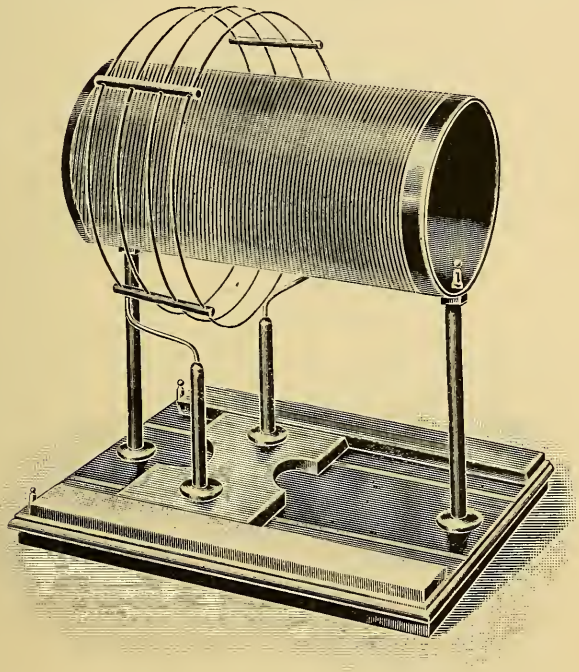

FIG. 29.—D'ARSONVAL RESONATOR.

and is in more general use than the D'Arsonval, partly on account of its smaller dimensions and the smoother effluve that can be obtained from it.

The Oudin resonator consists of a number of continuous turns of wire, which are wound usually on a wood framework of cylindrical form. The first few turns are

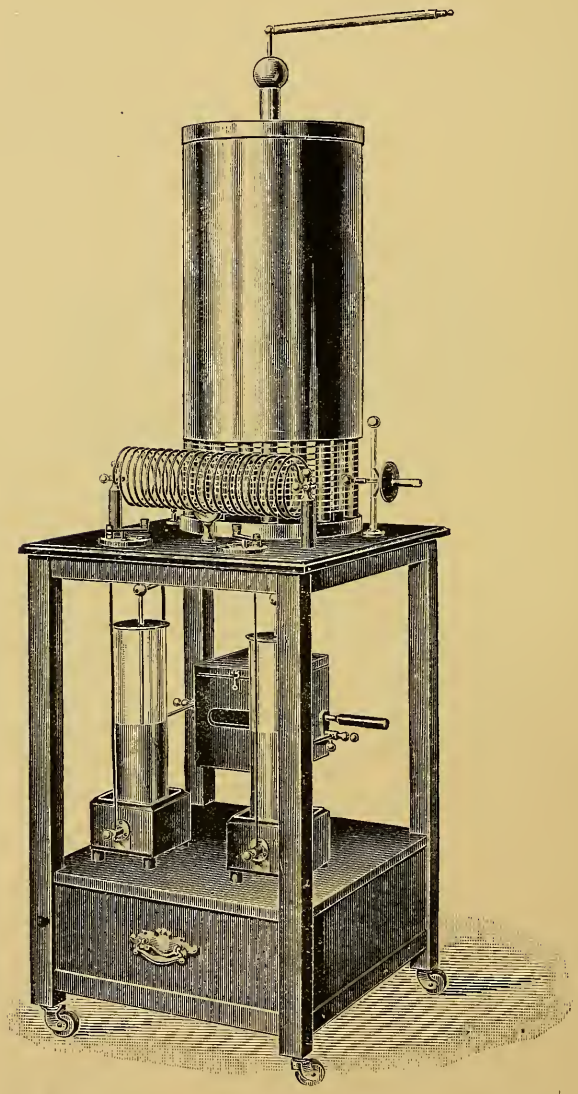

FIG 30.—COMPLETE HIGH FREQUENCY APPARATUS.

connected across the outer coatings of the condenser, and the other turns beyond this form the resonator. By varying the relation between the number of turns across the condenser and the resonator itself, the self-induction can be varied, and consequently the length of the brush discharge.

The various parts of a high frequency apparatus are mounted, as a rule, for convenience, either on one baseboard or a small table, as shown in Fig. 30. This table is very convenient, being provided with caster wheels and a drawer to contain various electrodes. This apparatus is also provided with coil terminals, earth terminal, and apparatus for varying or tuning, as it is sometimes termed, the resonator.

A somewhat different type of resonator to those previously described has recently been introduced by the Sanitas Electrical Co. This apparatus was originally made by Roycourt of Paris (Fig. 31).

The resonator is divided into two halves, and consists of about forty turns of fine wire inlaid into grooves of two ebonite discs. These two discs are separated by glass layers, and are arranged on either side of a solenoid, but are not connected.

The regulating of the strength of the current is controlled by sliding half, or both halves, of the resonator further away from the solenoid. This form of high frequency apparatus is particularly adapted for use with the static machine.

There is another form of resonator* which is described by Dr. Clarence Wright in Freund's "Radiotherapy."

* Reus' cones.

This apparatus consists essentially of a biconvex lenticular disc 33 inches in diameter, formed of ebonite or some other good insulating substance, upon which a layer of wire is coiled so as to form two cones united by their bases. The wire makes thirty-one spiral turns on each side of the disc.

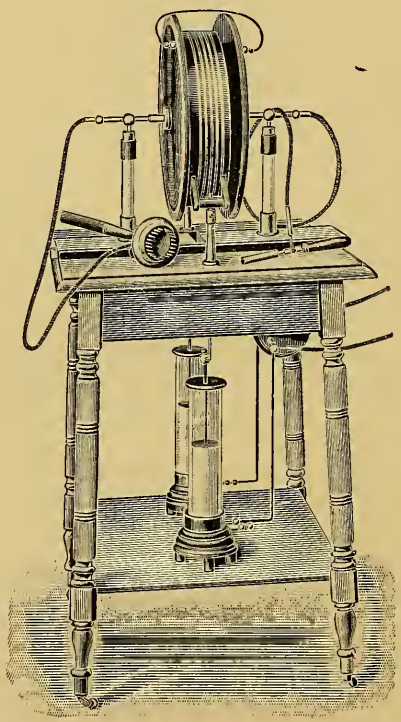

FIG. 31.—ROYCOURT HIGH FREQUENCY APPARATUS.

As the peripheral extremities of the two cones are continuous with each other, and the direction of their winding contrary, the inductive effects of the spirals is always a maximum. When in use the central extremity of one cone is connected with the external armature of a Leyden

jar, while the corresponding armature of the other condenser is connected by an adjustable contact clip with one of its intermediate spirals, in such a way as to obtain the maximum of output on the free central terminal, to which the electrode is attached.

The intensity of the high frequency current is controlled by varying the energy in the primary of the induction coil, by the length of spark between the inside armatures of the condenser, and by the induction of the solenoid or resonator.

FIG. 32.—HIGH FREQUENCY MILLIAMPÈREMETER.

When using the resonator, by altering the number of turns of wire across the condenser the length of effluve can be varied, and in the case of the solenoid the current can be controlled by decreasing or increasing the number of turns.

High frequency currents are measured by means of a special hot-wire milliampèremeter which is connected between the patient and the resonator or solenoid, as the case may be.

CHAPTER VIII.

THE PHYSICAL PROPERTIES OF HIGH FREQUENCY CURRENTS.

THE physical properties of high frequency currents may, for convenience, be divided into five groups:

A. Electro-static phenomena.
B. Dynamical phenomena.
C. The phenomena of induction.
D. The phenomena of resonance.
E. The phenomena of electric osmose.

A. ELECTRO-STATIC PHENOMENA.

Tesla first drew attention to the resemblance between electro-static phenomena of high frequency and those produced by working a Wimshurst, a Holtz, or other influence machine. Observation has proved that the effects are similar, but on a more extended scale. As subdivision may help to render them more easily remembered, the effects—luminous, chemical, condensatory, and inductive—which are comprised under the head of electro-static phenomena, will be separately studied.

Luminous Effects.—It is usual, under this head, to include both spark and brush discharges.

(*a*) *Spark Discharges.*—It has been calculated that the gigantic static machine (with plates measuring 7 feet in diameter) constructed for the Science and Art Department, South Kensington, is capable of producing sparks measuring 30 inches in air, if a condenser of suitable capacity could be found to stand the charge without being pierced by its enormous tension. Yet this limit can be easily exceeded, and sparks of more than double the length obtained, with currents derived from the secondary circuit of a Tesla coil.

(*b*) *Brush Discharges.*—When an ordinary electric machine is briskly worked in a dark room, but no sparks drawn from its collector, a slender brush of pale blue light will be observed issuing from the brass knob at the end farthest from the collecting comb. This is seen to better advantage when a metallic plate or disc is held a little distance from it, for the presence of a good conductor in the vicinity greatly increases the size and density of the diverging rays. The brush discharge then appears to be made up of innumerable twig-like radiations, which, on examination by the rotating mirror, are seen to be composed of a series of partial discharges, following one another in rapid succession.

The effects are more pronounced when an influence machine is worked after its collectors are removed and nothing is left but the rotating discs and their respective neutralizing brushes. The whole apparatus then bristles with electricity, and presents a most remarkable

appearance, being literally bathed in luminous brush discharges.

Similar effects in a still more intensified form can be obtained with a Tesla coil or a Spreadborough transformer. If currents derived from either of these sources be made to traverse two rather stout copper wires, placed parallel to each other in open circuit, and at a distance of 8 to 20 inches apart, brush discharges can be noticed shooting out at all points between them. Under favourable atmospheric conditions, this effluvation is powerful enough to convert the intervening space into a sheet of pale light. If the experiment be repeated with one wire wound into a circle 30 inches in diameter, in which the tip of the other is centrally introduced, a cone or disc of light appears, according to the arrangement made to secure insulation of the central wire. If this also be converted into a ring, 12 inches in diameter, and concentrically introduced into the larger circle, a nimbus is formed, which becomes a truncated cone as the circles are separated from one another, while still maintaining their planes parallel.

In addition to the luminous effects above mentioned, a peculiar hissing, crackling noise always accompanies this form of discharge.

Chemical Effects.—It is well known that electricity, whatever be its source, always gives rise to the same kind of chemical action. It was on this identity in their chemical effects that Faraday relied as the most convincing proof of their essential unity.

When a spark from an electric machine, Leyden jar,

or apparatus of high frequency, is received on a piece of white blotting-paper moistened with a solution of iodide of potassium, a discoloration is produced, due to the liberation of iodine by chemical decomposition of the salt. The kind of chemical action, however, usually associated with currents of high frequency is the production of *ozone*, which reveals itself by its peculiar odour. Another instance of the same kind of chemical action, which is associated with these currents, is the production of *nitric acid* by the passage of sparks between the knobs of the discharger enclosed in the spark-box. This is most liable to occur when the atmosphere is moist and humid. It is due, as Cavendish has already pointed out, to the formation of nitrous compounds by the direct union of the nitrogen and oxygen of the air under pressure slightly above the normal. These, by further combination with the vapour of water, held in suspension, yield nitric acid. For this reason it is advisable that the spark-box be frequently cleansed to remove these compounds and lessen the pressure of the contained air.

Condensatory Effects.—This peculiar property, which currents of high frequency have in common with static discharges of high potential, was discovered by Lodge. He first demonstrated the condensation of smoke, dust, and other kinds of matter held in suspension in the medium surrounding the electric spark. In an atmosphere so vitiated, the passage of a disruptive discharge causes a precipitation of the particles on the walls and all surrounding objects.

Inductive Effects.—The intensity of the electro-static

FIG. 33.—PHOTOGRAPH SHOWING THE EFFLUVE FROM THE TOP OF THE RESONATOR, AND GEISSLER TUBES LIT UP BY INDUCTION.

fields is even more strikingly illustrated by Tesla's experiments.

An alternating current of 120 volts 30 ampères, derived from an alternating-current dynamo or from the street main, is passed into the primary of an ordinary transformer,* by which it is raised to one of 15,000 volts 0·24 ampère. This current is led into the primary circuit of the Tesla coil, traversing both spark-gap and condenser in so doing. The current in the secondary circuit, although one of very high frequency and tension, can nevertheless be passed through the body without causing pain or shock.

If the secondary terminals of the Tesla coil be connected with the arms of a discharger, to one of which a brass sphere is attached, and a metallic rod, held by a person touching the opposite arm, be approached to it, sparks of from 6 to 10 inches can be elicited. Even when no metallic conductor is employed, but the hand held with fingers extending towards the sphere, a luminous effluve can be noticed issuing from the finger-tips.

Vacuum tubes introduced into the electro-static field at once become brilliantly illuminated. To demonstrate this effect, no direct contact with either pole is needed, provided a Geissler, a Tesla, or a tube containing either loose or mounted specimens of fluorescent minerals, be used. But if a Hittorf or butterfly tube be employed, it must be connected with the free arm of the discharger, and brought close to the metallic sphere on the opposite arm.

* The secondary terminals of this step-up transformer are dangerous to life, and are to be carefully guarded against accidental contact.

CHAPTER IX.

PHYSICAL PROPERTIES—*continued.*

B. Dynamical Phenomena.

In a circuit traversed by an alternating current violent electrical disturbances are produced, not only in the actual circuit of discharge, but also in all conductors connected with it. The least addition of a capacity at any part of the circuit is sufficient to set up in it stationary oscillations, the period of which corresponds with that of the primary current. The facility with which these disturbances are produced is proportionate to the frequency of the current employed. As the period of vibration in currents of high frequency is measured by hundred-millionths of a second, it is evident that their capacity for setting up stationary oscillations must necessarily be very great. Hence the most striking, if not the most characteristic, property of high frequency currents is the facility with which they circulate in open circuit. This can be demonstrated in several ways:

(*a*) When the poles of an adjustable spark-micrometer are connected, by means of a bifurcated copper wire, with any point in the solenoid of high frequency,* sparking

* The solenoid of high frequency in the D'Arsonval transformer connects the external armatures of the condensers to each other; in

will, under certain conditions, take place. For instance, sparks pass between the knobs of a spark-micrometer when the conducting wires are of unequal length, and also when a difference of capacity exists between the two poles; for capacity and self-induction, and not resistance, determine the potential difference between the poles of the shunt circuit so constituted.

(*b*) When an insulated conductor of large capacity, say one taken from an electric machine, is connected by a copper wire with any point in the solenoid of high frequency, it becomes the seat of stationary oscillations, *i.e.*, it is charged and discharged with every alternation of the primary circuit. The actual existence of these electrical disturbances can be established in several ways:

(1) If an electric lamp be inserted into the circuit of connection, it is at once rendered incandescent and shines with a bright light.

(2) If the connecting wire be wound into a helix, and a core of soft iron be inserted into the coil so formed, the temperature to which the iron is raised by the eddy currents is found to be sufficient to melt sealing-wax.

(3) If one end of the primary of a Masson coil* be united with one pole of the solenoid of high frequency, and the other with the insulated conductor, while at

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the Spreadborough transformer it connects one of the discharging pillars with a battery of Leyden jars. It is so called from being the seat of electrical disturbances set up by the oscillatory discharge.

* A Masson coil is made up of an inner and an outer coil, without a central iron core.

the same time the secondary is close-circuited by connecting its terminals with those of an incandescent lamp, the latter is immediately lit up, and continues to shine even though the conductor be detached. If the secondary circuit be itself interrupted and the lamp left attached to one terminal only, it continues to emit a feeble light, which can be greatly increased by holding the globe, or by coating it with tinfoil and connecting it to earth —the added capacity by condensation increasing the luminous effect.

(*c*) The dynamical properties of these stationary oscillations are equally well evidenced by Tesla's experiment of rotating motors connected by a single wire only. Here impedance—due to magnetic inertia of parasitic currents —seems to favour rotation. If one of the secondary terminals of a small Ruhmkorff coil, the primary of which has been short-circuited, be connected with any point in the solenoid of high frequency, and the other terminal be connected with a light metallic vane, rotation will be set up as the motor is brought into the electro-magnetic field so created.

This remarkable tendency which currents of high frequency exhibit, of circulating in open circuit, has given origin to certain methods of direct application. It also affords the only reasonable explanation of the sparks, effluve, and current discharges, which pass when an active electrode is approached to the body of a patient.

C. The Phenomena of Induction.

The electro-motive force of induction is directly proportionate to the product of the variation of the flux and its frequency. For instance, a current of 1 ampère, with a frequency of 600,000, will have the same inductive effect in a single spiral of a coil, as a current of 30 ampères with a frequency of 100 has in 200 turns of the same coil. A current, therefore, the period of oscillation of which is measured by hundred-millionths of a second, must possess a very powerful inductive effect.

When a small coil of well-insulated wire, wound in a layer of many turns about a central glass core, is introduced into the solenoid of high frequency, and its terminals connected with those of an electric lamp, the brilliant illumination of the lamp tells how powerful is the inductive influence exerted by the solenoid of high frequency on the wires of the enclosed helix. The same results are observed when, in place of the enclosed condensatory coil, an external coil is employed to form the secondary circuit. Even if the solenoid be removed and a straight piece of wire substituted for it, the coil wound about this wire can still generate a current sufficiently powerful to render the lamp luminous.

Similar induction effects, but on a proportionately larger scale, are observed when a lamp of 30 volts, 10 candle-power, is placed in derivation on a single wire of the cage of auto-conduction.

This property is principally employed to raise the tension of the current. As the number of turns in the

secondary circuit largely influences the tension of the induced current, it is evident that those generated in a coil of many turns of fine wire, enclosed in the solenoid, must necessarily be very great. So high is the tension of these currents that sparking can only be prevented by immersing the coil in a glass tube filled with oil, which must of necessity be also enclosed in the solenoid.

CHAPTER X.

PHYSICAL PROPERTIES—*continued.*

D. The Phenomena of Resonance.

It has been experimentally demonstrated that currents of high frequency are capable of producing powerful induction effects, and that oscillations are set up in all conductors connected with the discharge circuit. Similar oscillations are set up when a syntonic relation exists between two mutually reacting circuits. This is in accord with the principles of resonance; for periodic alternating currents must (other things being equal) have a more powerful inductive effect on a circuit having the same period of oscillation, than on one in which the period is different.

It is for this reason that the induction effects are perceptibly stronger for certain values of the capacity and self-induction of a circuit, having approximately the same period of vibration as another, than for neighbouring values on either side. These phenomena are the more easily understood by reference to certain analogous acoustic phenomena.

The intensity of a sound depends not only on the amplitude of vibration of the sounding body, but also on

the extent of surface it offers for contact with the medium of propagation. As the surface capacity of a vibrating-string or tuning-fork is very limited, it can only set in vibration a small mass of air, and therefore emits a feeble sound. When, however, it is made to impart its vibrations to an elastic body of greater capacity (capable of being thrown into a state of *forced* vibration), the intensity of the sound is immediately increased by reason of the added capacity. This intensification of sounds by means of a resonator or sounding-box is analogous to the increase of tension brought about by the inducto-resonators of Oudin and others.

Besides these forced vibrations, every elastic body has certain modes of *free* vibration natural to it. These can be set up by very slight impulses, provided they be repeated at certain fixed intervals of time. The accumulation of such impulses explains a number of acoustic and likewise electrical phenomena, generally classed together under the head of Resonance.

The vibration of a *resonator* tuning-fork, caused by the bowing of another adjusted to the same pitch, is an example of this co-vibration. The energy derived from the one is conveyed through the air in the form of waves till it reaches and is absorbed by the other, which then vibrates in unison with it. It is most essential to the success of this experiment that the two forks have exactly the same pitch, for if the prongs of one be loaded with wax (thereby altering the frequency of its vibrations) the experiment fails. Similarly, in the case of electrical resonance, it is essential that the two

reacting solenoids or circuits have the same period of oscillation.

The phenomena of free resonance can be equally well illustrated by making a tuning-fork set in vibration a column of air enclosed in a glass tube of not less than 16 inches in length. All that is required for this experiment is a tuning-fork, a glass tube of suitable length, and a vessel for holding water. By alternately raising and lowering the tube into the water, the length of the column of air, which most strongly reinforces the note of a given tuning-fork, can by trial be arrived at. It can also be proved, by varying continuously the height of the tube above the water, that any alteration in the length of the column of air is attended by a marked diminution in the intensity of the sound emitted. These phenomena of free vibration correspond most closely to those of simple electric resonance.

In connection with the subject of electrical resonance it must be remembered that the three most essential factors—capacity, self-induction, and resistance—of the two mutually reacting circuits must be so proportioned to one another that the period of electrical vibration of the two solenoids or circuits exactly corresponds. As might naturally be supposed, the phenomena of free resonance, although affording the better illustration of the subject, are not so strongly marked as those of forced resonance; and it is for this reason that the inducto-resonator of Oudin is now most commonly employed. As in the case of the vibrating column of air, the exact conditions under which the most perfect resonance is

established, although theoretically deducible, are in practice only arrived at by extended trial. Once this is attained, and the two reacting circuits made to vibrate in unison, it will be noticed that any alteration in the relative length of the two solenoids is attended by a diminution in the size of the effective spark.

The chief use made of resonators in electrotherapy is to increase the tension of the current, and to create a more powerful electro-static field in its vicinity. This can be practically demonstrated by repeating the experiments made to establish the existence of the electro-static phenomena of high frequency already described.

E. The Phenomena of Electric Osmose.

Porrett's researches show that when a strong current is led into a liquid contained in a Daniel apparatus—a **U**-shaped tube fitted with a porous partition between the electrodes—a mechanical current is set up, which forces a part of the liquid through the central porous diaphragm and causes it to stand at a higher level on the kathodic side of the partition than on its anodic side. The extent to which this phenomenon, known as "electric endosmosis," is manifest, depends on the conductivity of the liquid and the specific dialytic capacity of the intervening diaphragm for that liquid; for with liquids that are bad conductors, and a diaphragm that they readily saturate, the effect is most easily demonstrable.

"If Porrett's experiments," says Reus, "be repeated with a fluid circulating through a porous diaphragm (that in one arm being subjected to a positive pressure by

means of an air-pump, while a negative pressure is created in the other by partial exhaustion) the rapidity with which the fluid passes through the diaphragm depends on the direction of the electric flux, being increased when the directions of the current and of the circulating fluid coincide, and retarded when they are opposite.

"If, instead of a simple fluid, a standard solution of two or more mixed salts be employed, it is found that the relative proportion of the salts in the dialyzed fluid varies materially from that of the standard solution, the amount of each present depending on (*a*) the nature of the individual salt, (*b*) the degree of saturation of the standard solution, (*c*) the nature of the diaphragm, and (*d*) the direction of the electric flux.

"When two diaphragms are employed and the current periodically reversed, the pressure of the liquid in the centre compartment steadily rises, and causes the diaphragms to bulge outwards; while quantitive analysis of the fluids between and on either side of the partitions shows that the relative percentage of the different salts, present in samples taken from each of the three compartments, differ, not only among themselves, but also from that in the standard solution.

"This peculiar property of alternating currents is of great practical interest, as it affords an explanation of cataphoric phenomena and the movements of the ions on the one hand, and of the resolution of tumours, chronic indurations and exudations, under electrical treatment, on the other."

CHAPTER XI.

THE APPLICATION OF HIGH FREQUENCY CURRENTS.

THE following are the principal ways of administering high frequency currents.

I. Derivation.
II. Auto-conduction.
III. Condensation.
IV. Local applications.

I. DERIVATION.

In this, also called the direct method, the patient is connected to two points of the solenoid. On account of the phenomena of self-induction, the solenoid offers a great resistance to the current, which consequently more readily traverses the derived circuit of which the patient forms a part. If an electric lamp be placed in the circuit (Fig. 35), it will immediately be lit up, showing the passage of the currents. When this method is adopted the patient may lie on a couch, and hold in his hands handles made of metal which are connected with two points of the solenoid; or, if it should be wished to direct the currents more particularly to any part, electrodes made of plates of tin should be

placed on different parts of the region it is desired to treat. For the treatment of the upper limbs, one electrode should be placed at the back of the neck, while the other is placed on the hand; in the case of the lower limb, one electrode should be placed on the lumbar region, and the other placed on the foot. If both arms or both legs are to be treated at the same time, two electrodes can be attached, by means of a bifurcating wire, to one point of the solenoid, and placed on the two hands, or on the two feet, as

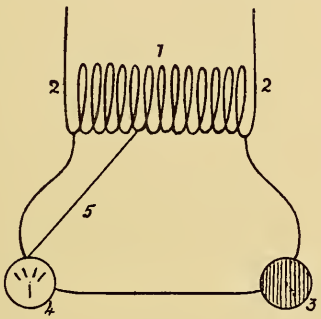

FIG. 34.—DIRECT APPLICATION.

1, Solenoid; 2, from condensers; 3, patient; 4, milliampèremeter; 5, movable contact to vary intensity.

the case may be, the other point of the solenoid being connected by a single wire to the electrode placed on the neck or lumbar region.

The intensity of the current may be varied by altering the distance between the points of the solenoid. D'Arsonval experienced as much as 3 ampères without any inconvenience. Care should be taken that the electrodes are well in contact with the skin, as otherwise uncomfortable sensations may be produced; the electrodes should also

be of sufficient size, as, if they are too small, they cause a slight erythema.

If the electrodes or handles are covered with chamois leather or flannel, this should be well moistened with water before they are applied in order to insure a good

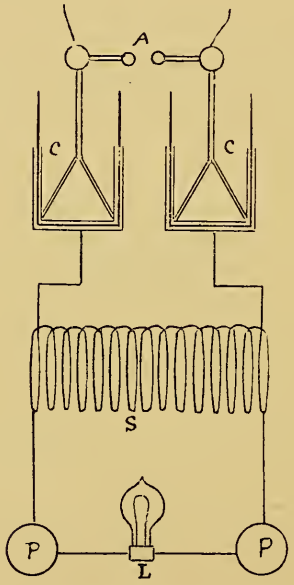

FIG. 35.—DIAGRAM OF EXPERIMENT.

A, Spark-gap; C, condensers; S, solenoid; P, patients; L, lamp.

contact; it is as well, also, to wet the skin at the part the electrode is to be applied.

When these precautions are taken the currents will cause no inconvenience, nor any muscular contractions.

In this method two kinds of applications may be made—viz., (*a*) *stabile*, where both electrodes are kept stationary

at the parts to which they are applied; (*b*) *labile*, where one electrode is kept stationary, while the other is moved about over the part to be treated.

The sitting should not at first be longer than from five to ten minutes, the duration being gradually increased up to twenty minutes as the patient becomes accustomed to the treatment. It should be borne in mind that any local application will, after a time, cause some inflammation, even of healthy tissue.

II. Auto-conduction.

In this method the patient is placed in the interior of a large solenoid, which is traversed by high frequency currents, without any direct connection with its spirals.

The solenoid or cage of auto-conduction is a large helix, 7 feet long by 36 to 48 inches in diameter, formed of 18 to 20 turns of stout copper wire (15 to 20 millimètres), ribbon, or tubing.

Its spirals are held in position by suitable insulating supports, which may either be cords and tapes of silk or of specially-prepared flax, or pillars and bars of ebonite or well-paraffined wood.

As the solenoid is intended for the reception of the body of the patient, it must be sufficiently large and spacious not only to accommodate it, but also to allow of easy access and enclosure. Those of the dimensions above mentioned have been found to well serve the purpose.

There are two chief types of solenoid in general use, the one intended for use in the vertical, the other in the horizontal position.

The arrangements of the wire spirals and their number differ in the apparatus of different makers. In some forms of the large upright solenoid the wires are permanently fixed to the wooden framework of the cage, a

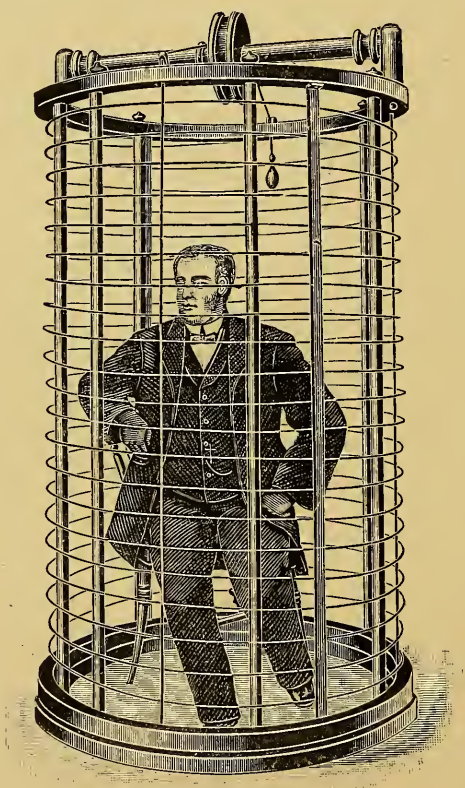

FIG. 36.—AUTO-CONDUCTION CAGE.

door being provided to admit the patient; in others the wire coils are suspended by silken tapes or cords, and can be drawn up like a venetian blind to afford access. The break in the continuity in the wire of the spirals in the

first case causes a certain amount of sparking and interruption in the flow of the current, and is for this reason not so advantageously employed as the other, which, when not in use, can be drawn up to the ceiling so as to place more space at the disposal of the operator. In the horizontal model the wires are either fixed about the insulating

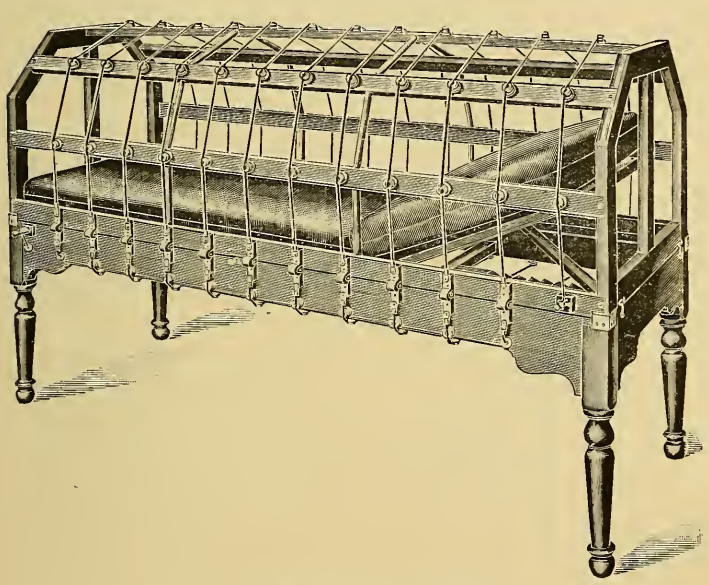

FIG. 37.—HORIZONTAL SOLENOID.

couch, or else they can be drawn into position, after the patient has been placed upon it, by a cord and pulley arrangement.

Owing to the intensity of the electro-magnetic field in which it is placed, the body of the patient becomes the seat of very powerful induced currents, which not only play over its surface, but also penetrate deeply into its

substance. The presence of the induced currents can be experimentally demonstrated in the following way:

If a neutral capacity—say the hand of the operator—be introduced between the wires of the cage, without touching them, and brought in relation with the body of the patient, a shower of fine sparks can, in the dark, be noticed passing between them. A subjective sensation of prickly warmth in the parts thus approached to each other is experienced by both operator and patient, but more so by the former; for the sparks which radiate from an electrified body are much less painful than those which impinge upon it, when it is a neutral capacity that receives a discharge from an active electrode approached to it. Similar effects are observed when the patient, using the same precautions, extends his hand through the wire spirals towards a passive body placed outside the cage. This experiment is always successful, and is a direct proof of the existence of induced vibratory currents on the surface of the body.

If the subject of the experiment be made to hold in each hand a small metallic disc, connected with one terminal of an electric lamp so as to form a loop circuit, the lamp is brought to incandescence by the intensity of the induced currents traversing it.

The effects of auto-conduction are very much the same as those of condensation.

CHAPTER XII.

THE APPLICATION OF HIGH FREQUENCY CURRENTS —*continued.*

III. Condensation.

When treated by this method the patient becomes one of the two armatures of a condenser. This is accomplished by the patient lying on a couch which is constructed as follows. Underneath the mattress is a sheet of some metal, such as zinc or tin, running the entire length of the couch; this is connected with one end of the solenoid. The other end of the solenoid is connected with two metallic handles, which may be either loose or fixed to the woodwork of the couch; these handles are held in the patient's hands. In this way the body of the patient is one armature, the sheet of metal directly underneath the mattress is the other armature, while the insulating mattress is the dielectric, representing the glass of a Leyden jar. The system may be traversed by a current of an intensity up to one ampère, the condenser charging and discharging at every oscillation.

An experiment illustrating the scheme of application by condensation consists in attaching an incandescent lamp to one end of a solenoid by a single wire. If this

be taken in the hand, and especially if the other hand be brought near the other end of the solenoid, the film in the lamp glows brightly. In this case the film is

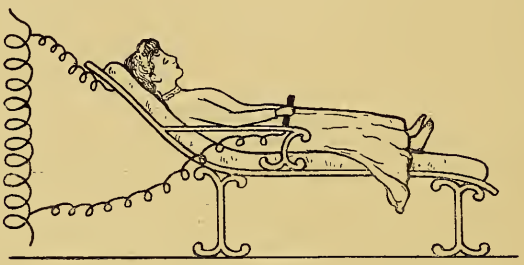

FIG. 38.—CONDENSATION.

one armature, the moist skin the other armature, while the glass of the lamp is the dielectric.

The condensation couch has been given various forms

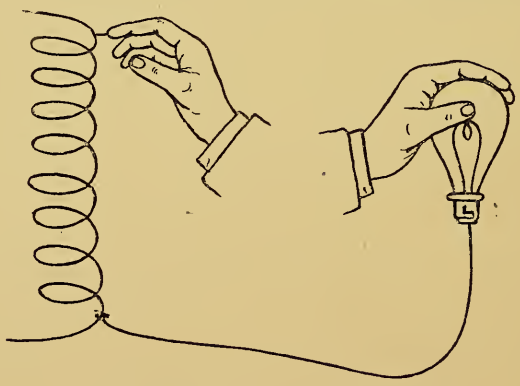

FIG. 39.—DIAGRAM OF EXPERIMENT.

by different makers. In some it is a massive, cumbersome article of furniture, in others its dimensions have been reduced to a size that renders it more awkward than efficacious.

For consulting-rooms in which the amount of available space is limited, the bent-wood couch shown in Fig. 40 is most suitable. It is at once strong, useful, and elegant, and does away with the multitude of unseemly expedients that have to be resorted to in order to render the chair-condenser effective. It, moreover, allows the patient to

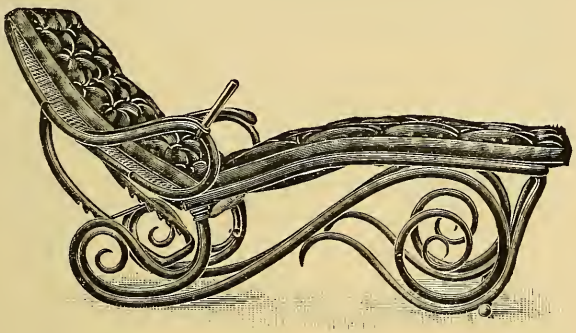

FIG. 40.—CONDENSATION COUCH.

rest in an easy reclining position, the advantages of which are well known by the experienced operator.

IV. Local Applications.

The effluve, or brush discharge, obtained from the resonator is applied by means of special electrodes designed for this purpose. The most common pattern takes the form of a disc (Fig. 41, No. 1), from which project a number of fine points. The disc is attached to a long insulating handle.

These electrodes are connected directly to the top of the resonator, and held at such a distance from the particular locality which is under treatment, that the

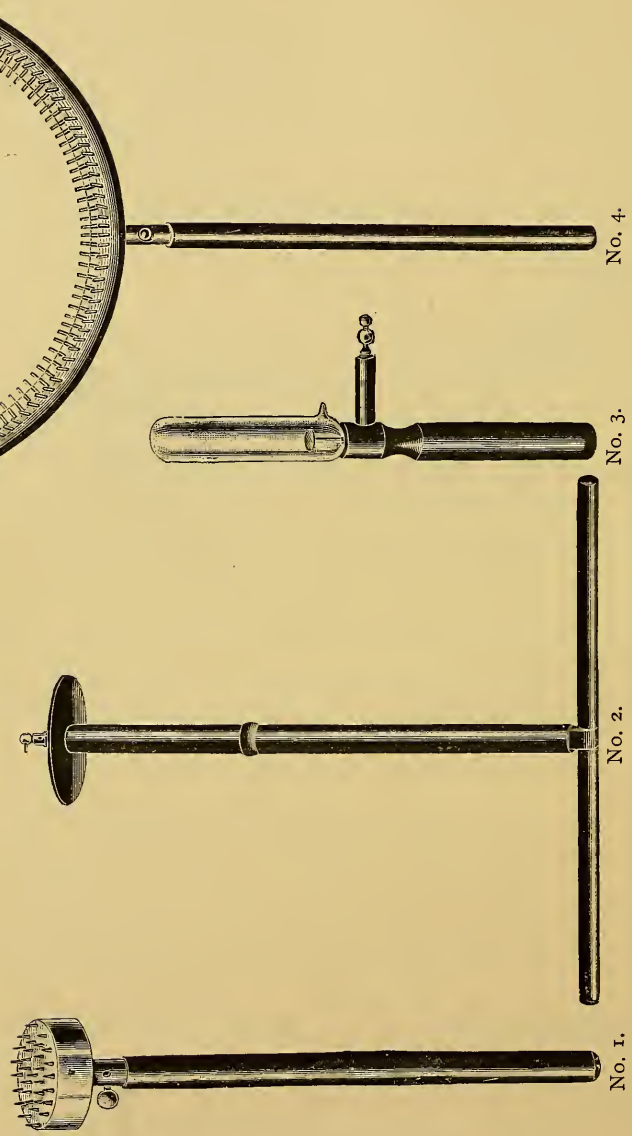

FIG. 41.

No. 1, Brush electrode with ebonite handle; No. 2, spinal electrode, of ebonite, with metal core extending through the stem and crosspiece; No. 3, glass electrode with ebonite handle; No. 4, thorax or crescent electrode with ebonite handle.

brush discharge plays upon it without any actual sparks passing. Glass electrodes are also used for applying the effluve. These may be either exhausted, or filled with

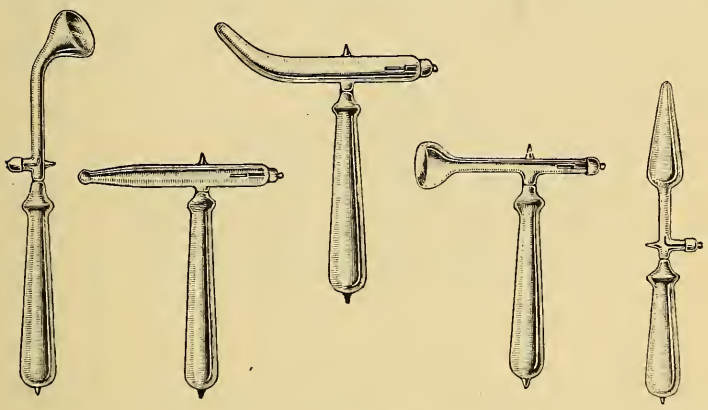

FIG. 42.—VACUUM ELECTRODES.

a saline solution. They are of various forms, both for internal and external application, being placed in actual contact with the tissues. These glass electrodes may be

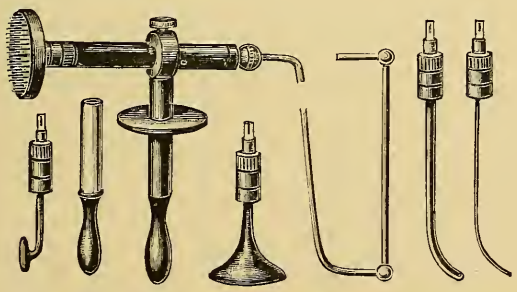

FIG. 43.—CHAPLIN'S UNIVERSAL HOLDER AND ELECTRODES.

exhausted sufficiently highly to produce a small quantity of X rays.

In Fig. 43 an insulating handle is shown, which is pro-

vided with a gauge into which the various electrodes can be fixed.

The cataphoresis electrode (Fig. 44), made by K. Schall, will be found most useful for applying the discharge from the top of the resonator to large areas, such as the

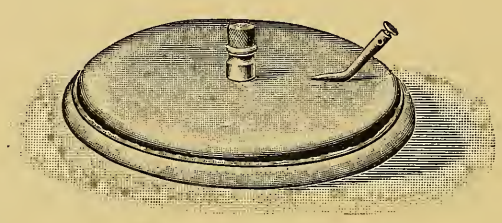

FIG. 44.—CATAPHORESIS ELECTRODE.

abdomen, chest, or back. It has a diameter of 8 inches, and consists of a disc of aluminium, over which parchment or a pig's bladder is fastened.

It should be three-parts filled, through the hole at the top, with warm water, so as to present a comfortable warmth to the skin; the whole should be wrapped in a silk handkerchief, and the membranous surface applied to the part to be treated. No sensation whatever is felt by the patient.

A new roller vacuum electrode has recently been introduced by Messrs. Waite and Bartlett, New York. By its use it is claimed that any possible discomfort, caused by overheating of the electrode during a prolonged and extended application, may be avoided.

PART II.

THE PHYSIOLOGICAL EFFECTS OF HIGH FREQUENCY CURRENTS.

CONTENTS OF PART II.

CHAPTER I.

INTRODUCTORY.

As the study of the systemic effects of high frequency currents is a corollary to the well-known rule, that rational therapeutics must be grounded on a sound physiological basis, it is needless to dwell on its importance. A little consideration will show how largely a knowledge of the physiological action of these currents has been instrumental in determining the field of their therapeutical application. It must, however, be remarked that all the properties claimed for them are not of equal consequence, nor are they to be regarded with the same degree of certainty; for experimental research, which has firmly established the unvarying constancy of some, has, in the case of others, led to results so diverse and contrary that these for a time must remain an open question, to be decided by a more extensive and careful investigation. It is not improbable that increasing knowledge will prove that many of these seeming contradictions are not such in reality, but that the differences in the facts observed are to be ascribed to certain modifications in the technique and conditions of the experiments, an opinion to which most writers incline. The well-known variations in the

capacity and resistance of the human body, and the influence which alterations in the duration and intensity of the currents employed have upon the reaction, afford a reasonable foundation for these inferences.

As an acquaintance with the circumstances by which these variations are brought about may help the reader to reconcile the conflicting statements made by writers in dealing with the physiological action of high frequency currents, they will be considered at some length.

A. Circumstances affecting the Electrical Capacity of the Body.

De Metz, who has devoted some attention to the subject, says that a comparison can be instituted between the electrical capacity of the human body and that of an ellipsoidal conductor of the same size, to which a theoretical value can be assigned. He finds that the variations in its electrical capacity, which depend upon its relations to other conductors, do not exactly correspond with those deduced by theoretical computation from well-known formulæ, being, as a rule, somewhat more than would be expected from these calculations. Leaving all condensatory effects out of the question, one may say that, not only can the human body be charged like any metallic conductor, but also that its capacity, when so charged, remains constant, according to the conditions of the experiment, for all values between 100 and 1,000 volts. As its capacity is equal to that of a metallic conductor of like size and dimensions, it is found that the quantity of

electric energy that can be imparted to the body varies directly with the size and configuration of the subject experimented upon. Again, it is to be remarked that its absolute value changes with certain conditions of posture and environment. Its normal value can be calculated by carefully isolating the person in question from all conducting surfaces, for these, by their proximity, influence its capacity. Similar variations are produced by changes of posture, but the normal capacity for a given posture is always a constant quantity for each individual.

B. Circumstances influencing the Resistance of the Body.

It is known that when the duration and intensity of the currents employed are constant, the three factors which influence the resistance of a conductor are its length, its sectional area, and the coefficient of its specific resistance. In the case of the human body, the last of these is by no means a constant quantity, for it has been found to vary with (*a*) the development and relative proportion of the various tissues of which it is composed, (*b*) with conditions of rest and exercise, and (*c*) with the state of health of the subject.

(*a*) *The relative development of the different tissues of the body.*—In spite of a similarity in form and general resemblance in structure, it is recognised that there are minor differences in the relative development of the various tissues of the human body that enable us to class persons as fat or lean, muscular or flabby, raw-boned or slender.

Using the heat engendered by resistance as the base of his calculations, Reus has been able to determine the relative resistance of the different tissues of which the body is composed. They are as follows: Muscles, 36 to 40 ohms; tendons, 72 to 95 ohms; nerves, 64 to 91 ohms; cartilage, 73 to 89 ohms; bone, 590 to 880 ohms; skin, 1,087 to 1,398 ohms. It is easy, therefore, to understand that the resistance offered by the body will vary with the degree of relative development of its tissues. As the resistance of the skin is the chief obstacle to their transmission, it is evident that currents which possess sufficient energy to overcome it can easily pass through the other tissues.

(*b*) *Variations caused by rest and exercise.*—As the muscles to a great extent determine the relative size of the body, it is only natural to suppose that if exercise can have an influence upon its resistance, that exerted by muscular activity must necessarily be a most important factor in determining the amount. This has been found to be the case, and it is generally recognised that muscular exercise, by causing an auto-polarization of the tissues, greatly increases the resistance. Henneker has demonstrated that the functional activity of secretory cells and glandular organs has a somewhat similar influence. He believes that the products of metabolic waste are the chief cause of this increase, and that if these be eliminated as fast as formed the resistance will not be affected.

(*c*) *Variations caused by the state of health.*—Not only does the resistance of the body depend upon the relative development of its tissues and the relative percentage of products of metabolic waste present in the system, but it

also varies with the state of health; for the morbid conditions and structural alterations caused by disease may be legitimately considered as a summation of the two cases previously considered.

It is known that the resistance of the body is diminished—

(1) In all depressed states of the organism, more especially in diseases affecting the nerve centres which control the vasomotor system—*e.g.*, chorea, neurasthenia, and melancholia due to degenerative changes in the central nervous system. In these diseases it is to be attributed to a hyper-vascularity and increased transpiration of lymph and serum in the tissues.

(2) In œdematous and engorged states of the lymphatic and circulatory system, provided that such transudation does not interfere with the conductive continuity of the cellular elements. Here the swelling and imbibition of the cells diminish resistance.

(3) In the non-atrophic myopathies and pseudo-hypertrophies, and all diseases characterized by muscular degeneration, when unaccompanied by vaso-constriction and a sensible diminution in size. It here appears due to a decrease or complete disappearance of animal electricity (caused by muscular activity), and the absence of auto-polarization in the tissues.

On the other hand, the resistance of the body is increased—

(1) In all pathological conditions of the nervous system characterized by exaggerated vaso-constriction—*e.g.*, hysteria, epilepsy, general paralysis, melancholia, etc.

(2) In all diseases in which keratinization of the epidermic cells is a marked sign, as scleroderma, elephantiasis, and beri-beri in the atrophic stage.

(3) In all diseases characterized by extreme emaciation, as the cachexias and wasting diseases.

(4) In visceral and local effusions which, by separating the cells previously in contact with one another, interfere with their conductive continuity.

(5) In pyrexia, more especially when accompanied by intense congestive conditions of the skin. It is not improbable that pyrexia not only increases the amount of sensible heat, but also the amount of animal electricity, which, by auto-polarization, causes an increase in the resistance of the body.

C. Variations in Technique, etc.

Battelli has demonstrated that variations in the capacity and auto-induction of the apparatus employed produce alterations in the intensity and amplitude of the electrical oscillations, without affecting the period of vibration.

Doumer and Oudin have likewise proved that variations in technique affect the intensity of the oscillations and the currents dependent on them.

Reus has investigated the variations in the intensity of the effluve derived from a resonator by varying the calibre of the wire, and also by altering the capacity of the inducing solenoid. He pleads for greater exactitude in recording all details of the experiments, so as to render the facts observed really worthy of scientific attention,

and says: "It is to be deplored that most of the investigations hitherto made do not furnish us with sufficient data as to the conditions of the experiment to decide how much the results obtained actually contradict the observations previously made by other workers."

If this explanation of the causes of variations in results be remembered, the reader will escape much of the confusion caused by the conflicting statements of authors in treating of the physiological properties of high frequency currents. These can best be studied in relation to their effects (*a*) on the nervous system, (*b*) on the circulation, (*c*) on the respiration, (*d*) on elimination, (*e*) on heat production, and, lastly, (*f*) upon micro-organisms.

CHAPTER II.

THE EFFECTS OF HIGH FREQUENCY CURRENTS ON THE NERVOUS SYSTEM.

THE most singular, although not the most physiologically important, property of high frequency currents is that they are without effect upon general sensiblity and neuro-muscular contraction. It is, indeed, very remarkable that any current can be passed through the body, at a voltage and intensity powerful enough to render incandescent a whole chain of electric lamps of 125 volts, 1 ampère each, mounted in series, without causing the slightest bodily inconvenience.

D'Arsonval found that even when the intensity of the current was extremely high—3 ampères—the only sensible impression produced was one of inconsiderable warmth at the points of its penetration into the body.

It is this characteristic of high frequency which distinguishes it from all other forms of electric energy. The marvellous insensibility of the muscles and nerves to stimuli following one another in such rapid succession first attracted attention to these currents, and led to their further investigation.

Incredible as it may seem, it must be acknowledged

that although Hertz had discovered, and Joubert had demonstrated, this peculiar property of the oscillatory currents, yet it was not until D'Arsonval and Tesla had, by some very striking experiments, attracted attention, that any attempts were made to test their therapeutical utility.

Several hypotheses have been advanced to explain this remarkable phenomenon. These either attribute it to the physical qualities of the current, or to some peculiarity in the physiological constitution of the organism.

The chief of these are—

(*a*) The conductor impedance theory.
(*b*) The theory of extended penetration.
(*c*) The theory of inductive reactance.
(*d*) The theory of limited excitability.

(*a*) *The Conductor Impedance Theory*.—This is the theory maintained by Ratzikowsky, Vigouroux, and Galileo Ferraris. When a straight length of cable of large cross-section is traversed by a uniformly continuous current, the lines of magnetic induction due to the current do not all pass through the non-conducting medium surrounding it. A certain percentage of them —owing to the current traversing the central strands— pass through the substance of the conductor itself. In other words, the magnetic flux surrounding a strand which is centrally situated is proportionately greater than around one nearer to or at the surface. If such a cable be used for alternating currents of medium frequency, it is found that the currents, owing to the alternations in

their flux, are not given time to penetrate into its interior, but will, to a considerable extent, confine themselves to the surface of the conductor.

This accumulation of the currents on the peripheral surface not only increases the resistance of the cable, but also diminishes the number of lines of force passing through its interior. To express this very characteristic reaction of conductors to alternating currents, Perren Maycock has employed the term "conductor impedance."

The induction of the surface of a conductor, traversed by currents of high frequency, tends to develop, in its interior, currents of reciprocal density and opposite sign, which, by raising the resistance of the strands more centrally situated, limit the penetration of the currents; hence the expression "skin resistance" or "skin conductance," sometimes used as a synonym for conductor impedance.

From what has been already said, it is easily understood that a conductor which presents the largest surface in comparison with its sectional area is best suited to convey the currents. Hence it is that a tube or ribbon is to be preferred to a solid wire conductor for these currents; for the drop in electro-motive force is less for them than for the last mentioned. As the number of magnetic lines passing through the interior of a conductor is in inverse proportion to the frequency of the currents conveyed by it, it is easy to understand how it is that currents, the period of oscillation of which is measured by millionths of a second, tend to almost entirely confine themselves to the surface. It seems only natural, there-

fore, to attribute the absence of excitation to a lack of penetration of these currents, by reason of their extreme frequency.

Plausible as this hypothesis may appear, it is open to several very serious objections, the more especially as the majority of facts established by experimental investigation are diametrically opposed to it.

Vittoria Maragliano, by introducing an incandescent lamp into the thoracic cavity of a dog, has been able to prove that the calorific effects of alternating currents are very appreciably manifest even after they have been made to traverse considerable layers of living and dead animal tissue. He also noticed that the temperature of muscular structures was raised by the passage of the currents, although the amount of heat engendered was not sufficient by its propagation to raise the temperature of the body as a whole. His experiments clearly prove that the currents not only extend superficially, but also *do* penetrate the body substance, the amount of current circulating in the deeper layers being in inverse ratio to the cross-section of the body at that part. According to H. Lebon, these conclusions apply as much to currents induced by auto-conduction as to those conveyed to the body by the direct methods of application. Freund says that the researches of L. Hoonveg, and the experiments of Einthofen and Leyden, largely support Vittoria Maragliano's conclusions.

D'Arsonval, experimenting with a normal salt solution (0·7 per cent.), the coefficient of specific resistance of which is equal to that of the body, has noticed that the currents

passing through the centre of the solution attained to within a hundredth part of the value they possess at the surface.

It is evident, therefore, that the laws governing the transmission of alternating currents by metallic conductors cannot be applied to the human body, which, although not a bad conductor, is an electrolytic one with a considerable specific resistance. In such a conductor the penetration of the current is proportionate to its frequency and intensity and the coefficient of the specific resistance of the tissues.

Another objection that can be raised to this hypothesis is that it affords no explanation of the action of the vibratory currents upon metabolic exchange and tissue nutrition.

(*b*) *The Theory of Extended Penetration.*—This hypothesis was advanced by Tesla as an explanation of the absence of excitation. He is of opinion that the currents do not directly penetrate into the tissues at the points of contact with the active electrodes, but first diffuse themselves over the entire surface of the body, from which they pass perpendicularly at all points into its substance. Not only can no facts be adduced in support of this hypothesis, but it is also contrary to the results obtained by experimental observation. If this supposition were true, the size of the electrodes employed to establish contact with the skin should be without influence upon the reaction; for if the currents extend themselves over the surface of the body before they penetrate the tissues, they should be able to as readily diffuse themselves from

the surface of a small electrode as from one of larger capacity. Experience shows that this is not the case, and that a small electrode provokes a more marked local reaction than one of greater size.

(*c*) *The Theory of Inductive Reactance.*—This hypothesis, formulated by Texeira, has the support of Reus, Crooneg, Hankermann, and Leipseg. It is generally recognised that the frequency and the wave-form of alternating currents have a considerable influence upon the resistance of the conducting medium. The crowding of the current to the surface of the conductor induces in the subjacent parts a current of reciprocal potential and opposite sign, which greatly increases the resistance offered by these parts to the entrance of the currents. In the case of the human body, Henneker has shown that the induction of the surface tends to increase the amount of animal electricity present in the tissues, which, by auto-polarization, increases their resistance.

As the number of alternations in currents of high frequency is extraordinarily great, the duration of the flux in a particular direction is thereby proportionately decreased, so that the currents are not given sufficient time to overcome the resistance of the tissues and provoke a response, for the bulk of their energy is frittered away in the production of molecular disturbances which, as Henneker has proved, characterize the period of latency. It is evident, therefore, that the theory of inductive reactance not only accounts for the absence of a sensible neuro-muscular reaction, but it at the same time affords a very reasonable explanation of the action of the currents

upon tissue nutrition as evidenced by thermogenesis and eliminatory excretion.

(*d*) *The Theory of Limited Excitability.*—This physiological hypothesis of D'Arsonval is that most generally adopted by French writers, but it is not so favourably received by the other Continental schools. Reus declares it a paralogical re-statement of the facts observed, rather than an explanation of the cause. He considers the very apt analogy instituted between the nerves of general and special sense a philosophical argument for believing in the existence of the phenomenon—which no one doubts—rather than a scientific discussion of its causes.

It is known that the nerves, both sensory and motor, only respond to stimulation when the number of excitations per second does not exceed certain fixed limits, for the current requires a certain amount of time to overcome the resistance of the tissues and attain a maximum intensity. Provided that the duration of each stimulus be not too brief, and the intensity of the current employed sufficiently great, each excitation induces a muscular contraction. If the number of stimuli be progressively increased, it is found that the individual contractions, instead of being distinct, become fused, so as to cause a permanent tetanic spasm of the muscle. This occurs when the number of excitations are between twenty and thirty per second. With a further increase in the frequency of stimulation, the phenomena of neuro-muscular contraction are still more in evidence until a maximum is reached, which occurs when the number of vibrations are between 2,500 and 3,000 per second.

The maximum is maintained between 3,000 and 5,000 undulations, after which it decreases as the number of oscillations continues to advance, until all sign of contraction is entirely abolished.

These observations led D'Arsonval to assume that *the nerves and muscles are so organized that they only respond to excitations falling within certain limits, and that they are perfectly insensible to vibrations following each other in such rapid succession*—an hypothesis which he believes should occasion no surprise when the reaction of the optic and auditory nerves to stimulation is considered. For it is known that the optic nerve can only distinguish ethereal vibrations when their number is between 497 trillions (red) and 728 trillions (violet), while they are quite unable to perceive other vibrations the number of which places them either below the red or beyond the violet. In a like manner the auditory nerve is only sensitive to vibrations of a certain intensity, no musical sounds being perceived which correspond with extremely low or very rapid vibrations.

In addition to the remarkable absence of excitation, it has been observed that alternating currents of high frequency exert an inhibitory influence upon the muscles and the nervous system. It is to this peculiar physiological property of high frequency that the anæsthesia, myasthenia, and changes in blood-pressure (due to vasomotor influence), are usually attributed.

Anæsthesia.—This is usually regarded as an example of the inhibitory influence of vibratory electrization upon the sensibility of the skin and tissues.

D'Arsonval was the first to discover that anæsthesia could be produced by *local* applications, the passage of the discharge—'la pluie de feu'—causing an insensibility, more or less pronounced according to the conditions of the experiment.

This diminution in excitability to ordinary stimulation is more in evidence in the parts submitted to the direct action of the effluve—as the skin, the mucosa, and the peripheral ends of the sensory nerves—than in structures more distant or deeply situated, although these, too, seem in some measure to be affected by the passage of the current.

D'Arsonval believes that one can produce by this means complete insensibility of the tissues, which lasts from three to twenty minutes, and is available for minor surgical operations. This statement of D'Arsonval has been largely questioned. Denoyés declares that the anæsthesia does not extend to a very great depth. Freund says that this insensibility of the tissues is very superficial, and almost inconsiderable. Sudnik, on the other hand, believes that it extends more deeply, the more especially as he has been able by this means to facilitate the reduction of dislocations. Boudet, Regnier, and Didsbury have found it of service in dental operations.

Oudin and Cruet, experimenting on the degree of anæsthesia necessary to render tooth extraction painless, declare that a sitting of four to five minutes' duration is sufficient for the incisors and canines, while one of five to eight minutes was required for bicuspids and molars, which possess more than one fang.

Doumer and Oudin believe that the degree of anæsthesia recommended by D'Arsonval for surgical operations is in reality the first stage of cell mortification, being similar to that produced by freezing the tissues.

Müller attributes it to the sedative action of the blue and violet rays upon the vasomotor filaments. Crooneg ascribes it to the ultra-violet rays, the rapidity of the rhythmic oscillations of which determines both its degree and depth.

Baedeker, who has put the various statements of D'Arsonval to the test of practical experiment, says: "We have found in this respect (*i.e.*, 'Aller jusqu'à l'anæsthésie complète') that there is not the slightest trace of complete anæsthesia. The variations in sensibility—to some of which I shall presently allude—were for the most part present in a very minor degree. I found, by comparison with a corresponding point on the opposite side of the body, that there was in all the cases investigated a slight diminution in sensibility, immediately after a sitting of five minutes' duration, for the sense of touch and pain.

"Dr. Cowl, Dr. Helkenberg, and myself were the subjects of the experiment in this case. A trial made ten minutes later showed that there was considerable hyperæsthesia in the now erythematous parts, both to tactile and painful stimulation (pricking with the needle).

"The results noticed in nine other cases under exactly similar conditions for the perception of cold and warmth were the same. A distinct decrease in the perception of cold was manifest immediately after the sitting, but a

like reduction in the perception of warmth could not with certainty be established. Ten minutes later there was well-marked hyperæsthesia for both cold and warmth present. The patient, for instance, could not now touch with the effluvated hand an iron bar the heat of which could easily be endured with the untreated one. I, personally, experienced the same. Of two equally cold iron bars, the patients mistook for the colder the one touched by the hand treated. When corresponding points on both hands were brushed over with ether, more cold was experienced in the part effluvated."

Myasthenia.—This term is used by Reus to express the diminution in muscular excitability which takes place when these tissues are traversed by currents of high frequency. It is more clearly manifest after treatment by the various methods of *immediate* electrization than by the *inductive* methods. It is also more marked under pathological conditions than in the healthy subject. Again, the involuntary muscular fibres exhibit it in a greater degree than do the smooth muscles of the body.

Sudnik has taken advantage of the relaxation thus produced in effecting the reduction of dislocations. Barboza has proved its usefulness in the treatment of vaginismus, anal spasm, and pyloric spasm due to hyperacidity and dilatation of the stomach. It is this property of high frequency which comes most prominently into action in the treatment of sphincteralgia and painful fissures of the rectum.

Vasomotor Effects.—These play an important part in

determining the alteration in blood-pressure noticed after treatment by vibratory electrization.

Haldwell Hance attributes the changes in blood-pressure to this cause. Schrieves believes that the great sympathetic trunks and the splanchnic plexus are more easily affected by currents of high frequency than by any other form of electric energy.

Reus expresses the opinion that myasthenia of the muscular coats of the intestinal vessels is the most reasonable explanation that can be offered of the vaso-dilation and fall in blood-pressure after vibratory treatment. Leduc asserts that vaso-dilation accounts for the sedative action of vibratory electrization upon the skin in pruritic conditions.

Bergonie has utilized the vaso-constriction caused by local application (the effluve) in the treatment of nævi; while Lutzenburger has proved its value in the cure of varicocele.

In summing up the effects of the currents upon the nervous system it must be remembered that—

1. They are without effect upon muscular contraction and general sensibility.

2. They exert an inhibitory influence upon the tissues so as to lessen their excitability to ordinary stimulation.

3. They have a considerable effect upon the vasomotor system.

CHAPTER III.

THE EFFECTS OF HIGH FREQUENCY CURRENTS ON THE CIRCULATION.

In treating of the effects of high frequency currents upon the circulation, a distinction must be drawn between that of general and local D'Arsonvalization. The former includes the methods of direct and inductive application, as derivation, condensation, and auto-conduction; the latter refers to treatment by effluvation alone.

General D'Arsonvalization.

In the *Archives d'Électricité Médicinale*, D'Arsonval, in speaking of the effects of these different modes of electrization upon the vasomotor system, says: "Le système nerveux vasomoteur, celui qui met en jeu la contractilité des vaisseux artériels et veineux, est éminemment excitable par les courants de haute fréquence." In proof of this influence upon vascular contractility, as well as of their effects upon the circulation, he mentions the following observations made by himself:

(*a*) In the rabbit one notices the vessels of the ear very rapidly dilate, as after a division of the sympathetic nerve.

This effect, however, is soon followed by an energetic contraction.

(*b*) The sphygmograph of Marey and the sphygmomanometer of Potain show, in the case of a human subject, the same results. The blood-pressure first falls, and then rises and remains at a higher level.

(*c*) When a slight incision is made into the paw of a rabbit, the blood flows more freely after than before the passage of the currents.

(*d*) By connecting a mercurial manometer with an artery—*e.g.*, the carotid of a dog—one sees an initial fall in blood-pressure of several centimètres, with a subsequent well-sustained rise.

Denoyés adds another to this list, and states:

(*e*) In man, as the result of a sufficiently prolonged sitting, one notices that the skin becomes injected and bathed in perspiration, this being the natural consequence of the action of the high frequency currents upon the vasomotor nerves.

Point (*a*).—Baedeker, speaking of the first of these proofs, says: "We were careful in all our experiments on blood-pressure and respiration, made with rabbits, to notice whether the ear presented the appearance above mentioned during general D'Arsonvalization; but we saw neither a filling of the vessels, which would indicate a lowering of the blood-pressure, nor any subsequent contraction causing increased arterial tension."

Sailer and Papiermeister, who have examined the mesenteric vessels of frogs treated by auto-conduction, found that the passage of the currents caused a well-marked primary

contraction of the arterioles, which almost obliterated their lumen, with a subsequent and more sustained paralytic distension of these bloodvessels when the sitting was prolonged beyond twenty minutes.

Crooneg, after the examination of the ears of six rabbits treated by auto-conduction, declares that no trace of a primary dilatation or subsequent contraction could be found in any of the animals.

Point (*b*).—With respect to blood-pressure in man, as estimated by means of a sphygmomanometer, Baedeker, as the result of various experiments, remarks: "It must be insisted on that in no case have we been able to confirm D'Arsonval's statements regarding a fall in blood-pressure at the commencement of D'Arsonvalization."

Earvalho declares that he has found "no alteration in blood-pressure due to D'Arsonvalization in cases treated by simple auto-conduction. When, however, a sensible reaction was produced by local applications to the skin of very powerful currents, a fall in blood-pressure took place."

Moutier claims to have reduced, by means of a weekly sitting of auto-conduction of from twenty to thirty minutes' duration, increased arterial tension when it was dependent upon pathological conditions. He attributes the reduction to alterations in nutrition caused by this method of treatment.

Sailer and Papiermeister tested the influence of auto-conduction, condensation, and derivation treatment on thirty-four cases. In summarizing, they say: "In eight cases treated by derivation we found an initial fall in

blood-pressure in two cases of 1 centimètre, and in one case of 2 centimètres; in the others no lowering of blood-pressure took place. In fourteen cases treated by the condensation method we noticed a fall of 1 centimètre in six cases, of 2 centimètres in two cases; in the remaining six cases the blood-pressure rose steadily from the commencement of the sitting."

In conclusion these scientists remark: "From our experiments we are forced to conclude that (*a*) the initial fall in blood-pressure is not a constant consequence of general D'Arsonvalization; (*b*) it is most frequently manifest in the *contact* methods of application; (*c*) a rise in blood-pressure sets in early during D'Arsonvalization, and is progressively advanced throughout the sitting; (*d*) the pressure gradually falls after the cessation of treatment to below the normal, and remains low for at least three hours after the termination of the sitting."

Point (*c*).—With respect to D'Arsonval's third proof of the action of the currents upon the vasomotor system, Baedeker says: "I now come to speak of point (*c*). D'Arsonvalization is supposed to cause the blood to flow faster from the incised foot of a rabbit. First of all one sees no blood at all flowing from the wounded foot, particularly if one only makes 'une légère incision,' as D'Arsonval prescribes. We have, nevertheless, repeatedly counted the outflowing drops of blood before, during, and after D'Arsonvalization. The results, however, are so various that I will not even quote them. The only thing they prove is that his experiment, if he arranged it in the manner described by him, furnishes no evidence at all."

Crooneg also acknowledges that this experiment of D'Arsonval proved, in his hands, a failure.

Sailer and Papiermeister also tried D'Arsonval's experiment on the rabbit's foot, and met with a similar want of success, but by somewhat varying the experiment they were able to prove an increase of arterial tension after D'Arsonvalization.

Point (*d*).—With reference to point (*d*) of D'Arsonval's experiments, Baedeker, as a result of his experiments, says: "We may say that we have proved, contrary to D'Arsonval's researches, that D'Arsonvalization does not influence the blood-pressure in the carotid of the rabbit This difference from the results obtained in our experiments upon human beings is not at all surprising, for we have already seen that in man the influence of the currents varies so much in different subjects that this difference in influence of the blood-pressure between man and animals calls for no special remark."

By comparison of the results obtained by these investigators, it will appear that the effects of high frequency currents upon the vasomotor system are clearly demonstrated, the two chief points in connection with the subject being—

(*a*) The fairly constant rise in arterial tension during D'Arsonvalization; and

(*b*) The fall in blood-pressure some little time after its discontinuance.

The initial fall in blood-pressure described by D'Arsonval seems to be peculiar to certain modes of application rather than a general accompaniment of all methods.

Local D'Arsonvalization.

In treatment by effluvation, or local D'Arsonvalization, there is a general agreement between writers as to the effect of this method of application upon the circulation and blood-pressure.

Moutier, Doumer, Leduc, and Oudin have very clearly demonstrated that—

(*a*) The passage of the discharge causes, at the point of application, and for from 1 to 2 centimètres round it, a well-marked spasmodic anæmia of the skin, which becomes chalky white, while the papillæ are erected. This blanching of the skin is due to a very energetic vasomotor constriction. A little later it is seen to give place to an erythematous blush, as well marked as the preceding contraction, but of longer duration.

(*b*) A very considerable increase in blood-pressure can by this means be produced. Moutier, by the application of an electrode connected with an Oudin's resonator to the spinal column of a man, and by working chiefly in a downward direction, was able to produce by the discharge of the effluve a rise of pressure of 4 to 8 centimètres of mercury.

Doumer confirms this experiment of Moutier. Denoyés states that arterial tension can be more rapidly raised by this procedure than by any other method in use at present, not excluding the transfusion of artificial serum. Oudin, by employing the currents derived from a resonator, has, in an anæmic subject, increased the arterial tension by as much as 9 to 14 centimètres during a single sitting. Reus,

Crooneg, and Leduc have also noticed a similar rise in blood-pressure after effluvation.

(*c*) Oudin has examined by means of a sphygmomanometer the tracings of the capillary pulse. He found that when the effluve from a resonator touched any part of the body it instantly produced in the capillaries of the hand of the patient a spasmodic vasomotor contraction, which resulted in a marked decline of the general curve. He has also proved that a diminution of the amplitude of pulsation takes place, which in some cases almost amounts to a complete suppression. After the cessation of the treatment the pulse rapidly assumes its former character, but only regains its amplitude after a considerable period, during which the tracing records a progressively decreasing series of minor vasomotor oscillations.

Doumer and Oudin therefore recommend this treatment in diseases characterized by diminished activity in the nutritive exchanges, and in chronic local inflammations due to arterial or venous stasis.

In addition to these changes in blood-pressure it can be noticed that the blood itself undergoes some modifications under D'Arsonvalization. The consideration of this point must, however, at present be deferred.

CHAPTER IV.

THE EFFECTS OF HIGH FREQUENCY CURRENTS ON THE RESPIRATION.

In treating of the physiological action of the oscillatory currents upon the circulation, a distinction was made between the systemic effects of local and general D'Arsonvalization.

So also, in dealing with the physiological effects of the vibratory currents upon respiration, it can be noticed that local D'Arsonvalization occupies a position apart from the other methods of application usually classed together under the head of general D'Arsonvalization.

The Effects of Local D'Arsonvalization.

As no question has as yet been raised regarding the effects upon respiration of this method of electrization, it were well to record all that is at present known about its action. Beaumont and Reeverton have, by their experiments upon rabbits and monkeys, clearly demonstrated that—

(*a*) The activity of the respiratory centres is considerably increased *by effluvation of the vertebral spine*, so that the respirations become both quicker and deeper, while at the same time more respiratory work is done.

(*b*) *Effluvation of the thorax*, on the contrary, causes accelerated and shallow breathing, alternating with slow and deep respirations, with an occasional stoppage in the position of expiration.

(*c*) *Effluvation of the anterior abdominal wall*, more especially when the discharge is directed against the epigastric region, causes the respiratory movements to become very rapid at the commencement of the sitting, with a subsequent slowing of the movements, which becomes more marked the longer the treatment is continued. The pause here is in the position of a full inspiration.

(*d*) *Effluvation of a limited area of skin on either the upper or lower extremities* seems to be without any special effect upon the respiratory movements.

The Effects of General D'Arsonvalization.

Although it has not as yet been experimentally established, there are nevertheless many good reasons for supposing that the physiological action of the vibratory currents upon the processes of respiration does not to any great extent depend upon the method of application employed. Denoyés, in dealing with this subject, refers to D'Arsonval as his authority for saying that the effects are much about the same for direct application, condensation, and auto-conduction, although the last is the method which has almost exclusively been employed in studying the action of the currents upon respiration.

D'Arsonval claims for the currents of high frequency and tension a considerable influence upon the respiratory

processes, both in man and the lower animals, when treated by the cage method. This, he asserts, is clearly evidenced by—

(*a*) *The increase in the number and depth of respirations* during a sitting of auto-conduction. In proof of it, he brings forward the tracings taken of the respiratory movements by a recording lever upon a revolving cylinder of Marey.

(*b*) *The increased activity of the processes of respiratory combustion*, or, in other words, *the amount of respiratory work done*. This can be established (1) by the considerable increase in the amount of oxygen absorbed and carbonic acid gas eliminated in a fixed unit of time; (2) by the loss of body-weight that results from increased organic combustion; and, lastly, (3) by urinalysis.

With reference to point (1), he says: "When one compares the product of respiratory combustion before and after the action of high frequency, one sees a considerable increase in the amount of oxygen absorbed and carbonic acid eliminated in a unit of time." In support of this assertion he evidences an experiment made upon himself, in which it was found that the quantity of carbonic acid gas excreted rose from 17 to 37 litres per hour. Prodigious as this increase may seem, D'Arsonval is by no means inclined to consider it as the maximum, for he adds that it is possible to obtain "des nombres plus élevés."

In dealing with point (2), he mentions some of the conditions under which his experiments on the loss of body-weight were made. They are as follows:

1. The animal under experiment was placed in a solenoid.

2. The weight of the cage and its contents was ascertained by placing it on the scale of a Richard balance.

3. In order to eliminate the possibility of any error arising from loss of weight due to evaporation, a receptacle containing oil was provided for the dejecta of the animal.

4. The loss of weight sustained in a given time by the animal under experiment was then ascertained, both without and during electrization ; so that the results obtained under similar conditions could be compared, and the loss due to auto-conduction duly arrived at.

It was then found that a guinea-pig, which during its sojourn in the cage for sixteen hours without D'Arsonvalization had lost 6 grammes, lost 30 grammes in the same time when submitted to the action of the currents of high frequency.

It is as well to note, as Querton remarks, that D'Arsonval furnished no particulars as regards the temperature of the cage, or as to whether the animals were feeding during the time of the experiment. Denoyés, however, in dealing with the first objection, says: "It is necessary to remark that the warming of the cage by the current was insignificant, since the temperature was not raised one degree, and cannot in consequence have acted upon the animals under experiment." Baedeker, who has put these statements of D'Arsonval to the test of practical experiment, states:

"We can thus summarize the more essential points brought out by our experiments. They are:

1. "The respiratory quantity increased in seven minutes

during D'Arsonvalization from 6,140 to 11,600 c.c. per minute.

2. "Five minutes after the discontinuance of treatment the respiratory quantity decreased both in number and depth, although it still remained considerably greater than before D'Arsonvalization.

3. "In fifteen minutes after D'Arsonvalization the respirations became nearly normal."

Loewy and Cohn made experiments upon eight men, in whom they noted the influence of vibratory electrization upon the amount of oxygen consumed. Among these eight cases are two which proved that during D'Arsonvalization an increase took place in the consumption of oxygen over the normal physiological limit of 6 per cent.; in one case it amounted to 12·6 per cent., and in the other to 19 per cent. An increase of 6 per cent. over the normal limit was also shown in two other cases, but one of these in a subsequent experiment manifested no such increase.

Tripet investigated the action of high frequency upon internal respiration. In order to observe the activity of exchange between the blood and tissues, the blood was examined by means of Henocque's hæmatospectroscope, and the activity of reduction investigated by elastic ligature of the thumb, both before and after as well as during treatment by vibratory electrization. The results he obtained are as follows:

1. In thirty-seven cases the currents of high frequency had increased the activity of reduction of oxyhæmoglobin. This phenomenon was particularly manifest in diseases characterized by poor nutrition.

2. In ten cases of diabetes, in which before treatment the activity of reduction was greatly increased, the currents of high frequency reduced it to within normal limits.

3. It was only in six cases in which organic decay had made much progress that treatment was without effect, the activity of reduction steadily decreasing.

It is remarkable that there is almost always a simultaneous and parallel increase in the proportion of oxyhæmoglobin and that of the activity of reduction, this increase of oxyhæmoglobin being largely instrumental in determining the activity of reduction.

Guillaume has, by the same method, determined the influence of the vibratory currents upon the activity of reduction of oxyhæmoglobin in diseases characterized by malnutrition, as rheumatism, sciatica, chlorosis, anæmia, etc. His conclusions are the same. In all cases where an amelioration in the principal symptoms took place, there was also a modification in the reduction of oxyhæmoglobin. The increased activity of reduction was always accompanied by a similar increase in the amount of oxyhæmoglobin, thus proving that the improvement in general health and nutrition brought about by treatment had an important influence in determining the activity of exchange between the tissues and the blood.

On the other hand, Guilloz, who has investigated issue metamorphosis as evidenced by muscular structures, declares that he could not trace any increase in the absorption of oxygen due to auto-conduction. Although

unwilling to deny that an increased absorption of oxygen does take place, as D'Arsonval asserts, during respiration, he insists that it does not originate from any increase of oxidation occurring in the protoplasm.

It is evident, therefore, that currents of high frequency have an influence upon the processes of respiration, although it is not always manifest to the same extent in all cases submitted to electrization.

CHAPTER V.

THE EFFECTS OF HIGH FREQUENCY CURRENTS ON ELIMINATION.

It is generally recognised that the organic exchanges which take place in the body can, in a measure, be gauged by the excrementitious waste thrown out of the system. Since the kidneys play a very important part in the elimination of the bye-products of the internal economy, as well as offer the greatest facilities for accurate observation, it is only natural to suppose that the evidence afforded by the exercise of their functional activity can with safety be accepted as the touchstone of judgment in determining the influence of the oscillatory currents upon tissue metamorphosis. The effects of general D'Arsonvalization being more readily determined than the systemic reaction caused by local applications, it is the former methods of electrization that have been most frequently employed in the experiments made to ascertain the action of the currents upon urinary excretion. The effects of this mode of electrization upon the nutrition of the tissues, in so far as it is evidenced by the functiona activity of the kidneys, has from the first been chiefly studied from the clinical side. It is from this stand-

point that D'Arsonval approached the subject. His first observations were made on patients treated by direct applications with oscillatory currents of 350 to 450 milliampères. The duration of the daily sitting varied from ten to thirty-five minutes.

The results of experiments proved that currents of high frequency not only influence the amount of urine excreted, but also increase the elimination of nitrogenous extractives, more especially of urea, and the toxicity of the urine as well. When these investigations were subsequently extended to embrace the other two methods of general D'Arsonvalization (*i.e.*, condensation and auto-conduction), it was found that similar modifications of nutrition resulted from the action of applications made by these methods.

These statements of D'Arsonval are supported by a great number of independent investigators. In 1893 Morton found, as the results of electrization, that the amount of uric acid contained in the urine of patients suffering from chronic rheumatism diminished, while that of urea increased.

Lacailli proved by chemical analysis that the quantity of urea present in the urine of the cases treated by him steadily rose under electrization from 11 to 43, or even to 60, grammes.

Apostoli has shown that in his cases electrization gave rise to an increase in diuresis and elimination of urea, as well as causing an increase in the oxyhæmoglobin of the blood, the improved nutrition not only stimulating the desire for work, but also furnishing the energy necessary to sustain it.

Berlioz made as many as 761 chemical analyses of the urine of 280 patients treated by general D'Arsonvalization. As far as could be arranged, the patients were treated to a daily sitting of ten to thirty minutes (average fifteen minutes). Care was also taken to exclude any collateral influence, as the effects of special dietary or internal medication, which might vitiate the results. The action of D'Arsonvalization pure and simple could then be exactly studied. Under these conditions, it was found that currents of high frequency caused (*a*) an improvement in diuresis and in the elimination of excrementitious waste; (*b*) a considerable increase in the process of organic combustion; and (*c*), by converting a certain percentage of uric acid into urea, a reduction of their proportion (when increased) to the normal ratio of 1 to 40.

In comparing the reaction of patients to the different modes of general D'Arsonvalization, Berlioz places condensation first, and speaks of it as one which appears to have the greatest influence upon the nutritive processes —"qui paraît [plus active sur le processus nutritif"—as under electrization by this method the flow of urine, even when abundant, slightly increased, while the amount of urea, of uric acid, of the phosphates and chlorides eliminated was noticeably increased. He is careful, however, to point out that the percentage of uric and phosphoric acid maintained the normal proportion to the amount of urea excreted—a peculiarity which was equally well evidenced in treatment by the cage method.

G. S. Vinaj and G. Viette are of opinion that high frequency currents have an influence upon the nutrition of the body, which, by modifying the organic exchanges that take place in the tissues, produces an increase of nitrogenous metabolism. Their experiments were made on two healthy adults, in whom an equi-balance of nitrogen was maintained by a carefully regulated dietary. Their experiments extended over a period of nine days. The first three days were devoted to determining the normal amount of urine, and urinary extractives present in it. During the three succeeding ones they noticed the variations brought about by two daily sittings of auto-conduction of fifteen minutes each, while the remainder of the time was given to observations of the changes that took place after the cessation of treatment. They say that the quantity of urine excreted was not appreciably affected by treatment, for while in one case it remained much about the same, in the other—who had sweated somewhat profusely while in the cage—it was less. The acidity of the urine, on the other hand, was much increased by electrization, but fell after the discontinuance of D'Arsonvalization. They attribute the increase in acidity to a greater abundance of acid salts, formed by increased metabolism of proteid substances.

The total quantity of nitrogen and of urea excreted rose during the period of treatment, and fell, after its termination, to the normal. The elimination of phosphates was similarly affected, more being passed during the stage of electrization than either before or after.

These observations, though somewhat limited, agree

with those of Crooneg, although one observes minor individual variations in the different results obtained.

Denoyés, Marbre, and Rouvière have studied in more elaborate detail the variations in urinary excretion caused by auto-conduction. They experimented on three young adults, who were, during the whole period of observation, kept on a select dietary, the amount of fluid ingested being also as carefully arranged.

After three days on this special diet, the whole quantity of urine passed in the twenty-four hours was collected daily and divided into three parts, one of which was set aside for chemical analysis, another for ascertaining the toxicity of the urine, while the third was reserved for determining the point of congelation. These observations were made during the six days before, the three days after, and during the five days of treatment, by auto-conduction of six to twenty-five minutes daily, with a current of sufficient intensity to render incandescent an electric lamp of 30 volts, 10 candle-power, fixed to an induction ring in the interior of the large solenoid.

By this procedure it was found that—

(1) During the stage of treatment by auto-conduction the amount of urine increased, as well as the quantity of urea, uric acid, total nitrogen, phosphates, sulphates, and chlorides eliminated in the twenty-four hours.

(2) An increase occurred in the same period in the quantity of urotoxic substances eliminated in the twenty-four hours per kilogramme of living weight. This is evidenced both by the increase in the number of urotoxic

units, and by the higher value of the urotoxic coefficient found during D'Arsonvalization.

From these observations Denoyés arrives at the following conclusions:

1. Currents of high frequency applied to the body by the method of auto-conduction increase the elimination of urinary waste.

2. There is a general agreement in the indications furnished by all the methods of investigation resorted to.

3. The modifications observed during treatment are maintained during the succeeding three days, but always in a less accentuated form.

It is evident, therefore, that indications are not wanting which support and confirm D'Arsonval's observations on the influence of high frequency upon elimination and the internal nutritive exchanges.

CHAPTER VI.

THE EFFECTS OF HIGH FREQUENCY CURRENTS UPON HEAT PRODUCTION.

In spite of certain diurnal and other minor variations which take place even in health, it is usual, in speaking of the temperature of the body, to regard it as a constant quantity, and one that is independent of the temperature of the surrounding element in which it is placed. This equi-balance of temperature is maintained by variations in heat production and heat loss, which are under the control of a nervous thermogenic mechanism. It is well known that the respiration of every living tissue results in the production of heat, but the amount contributed by the different tissues is by no means proportionate to their mass or weight; for, while the metabolic changes that take place in contractile structures, more especially the muscles which constitute nearly one-half of the entire body-weight, account for the greater part (85 per cent.) of the heat generated in the organism, that furnished by the functional activity of the brain and glandular organs does not amount to more than 10 per cent., which leaves a small proportion of 5 per cent. to be made up by the other tissues of the body. Calorimetric observations have

proved that increased heat production can be brought about by excitation of the nervous thermogenic mechanism, or by a more direct stimulation of the tissues themselves to exaggerated metabolism.

Of the heat so engendered, not less than 76 per cent. is expended in providing for radiation and evaporation from the skin, somewhat more than 14 per cent. in warming and rendering moist the inspired air, while the remainder is employed in warming the food ingested, and in protecting against losses from kidneys and bowel. As the distribution of the heat losses by these different channels is relatively constant, it is obvious that, when the temperature of the body is a constant, the amount of heat generated in the organism can be roughly gauged—

(1) By estimating the amount of carbonic acid gas and watery vapour eliminated by the lungs, for this is directly proportionate to the quantity of heat produced, and inversely proportionate to the temperature of the surrounding atmosphere;

(2) By a more direct calculation of the amount of heat lost in respiration;

(3) By ascertaining the amount of heat lost by the kidneys; and, lastly,

(4) By experimentally determining the amount lost by radiation and evaporation from the skin.

Several theoretical considerations can therefore be adduced in support of D'Arsonval's contentions regarding the action of the vibratory currents upon thermogenesis. The chief of these are—

(*a*) The increase that takes place during D'Arsonvaliza-

tion in the number and depth of respirations, as well as in the amount of oxygen absorbed, and carbonic acid gas eliminated, by the lungs.

(*b*) A corresponding increase during electrization in the nutritive exchanges that take place between the tissues and blood, known as the internal respiration of the tissues.

(*c*) An increased elimination of urine, and of nitrogenous extractives found in it, during the time of treatment.

Insomuch as these point to an increase in tissue metamorphosis, do they also warrant the assumption that treatment by D'Arsonvalization is characterized by an increase in the quantity of heat produced by the tissues.

As the temperature of the body does not appear to be appreciably affected by this increase in the amount of heat produced under the influence of vibratory electrization, it is evident that the equi-balance of temperature is maintained by a corresponding increase in heat loss. For determining this quantity D'Arsonval made use of an apparatus which he calls an anemo-calorimeter. It consists of an athermanous cylindrical cage, formed of heavy cloth, in which the subject of the experiment is enclosed. The superior outlet is closed by a wooden disc, which prevents a too rapid dissipation of the heat given off by the body, and at the same time serves to direct the currents of air impinging on it into a funnel-like opening connected with a very sensitive Richard's anemometer. The principle of the apparatus is as follows:

The air in the space in which the subject of the ex-

periment is placed, under the influence of the heat evolved from his body, expands as its temperature becomes raised. Being thereby rendered lighter than the air without, it rises and creates an air current, the velocity of the flux of which can be exactly gauged by the number of revolutions the wind-wheel of the anemometer makes in a fixed unit of time. It is easy, therefore, by this means to estimate the quantity of heat given off by the body. In order to save time and facilitate observations, the apparatus is furnished with an index, which registers the number of calories set free.

By means of the anemo-calorimeter, D'Arsonval was able to determine the difference in the amount of heat given off by a person placed in its interior, both before and during D'Arsonvalization by the cage method. He found that the amount varied from 79·6 to 127·4 calories per hour, at a mean external temperature of 17° C. As this amount represents the heat loss by radiation and evaporation from the skin, as well as that given off during respiration, it can be reckoned to be not more than 80 per cent. of the increase produced by the action of the currents upon heat production. An allowance must also be made for the heat absorbed by the walls of the apparatus itself.

Bonniot has also investigated the effects of vibratory electrization upon thermogenesis. His experiments were made upon infants, treated by the condensation method. He made use of D'Arsonval's anemo-calorimeter, somewhat modified to suit the altered conditions of the experiment. To the outer surface of the calorimetric cage was

affixed a layer of sheet tin, which formed one armature of the condenser. The body of the child, resting upon a sheet of the same metal inside, was the other armature. The wooden side of the cage was the dielectric. By experiments made under these conditions, it was proved that an increase in the quantity of heat produced was effected by the action of the oscillatory currents; but this increase was preceded by a momentary fall in heat production.

Bordier explains this apparent contradiction by analogy to the effects of cold baths on the system, which, after a momentary contraction of the surface capillaries due to chill, cause a well-marked glow of warmth, which is manifest even while in the bath; but if the bathing be too prolonged, a subsequent and more permanent coldness is produced.

Sailer and Papiermeister, on the contrary, believe that the initial fall in heat evolved is due to a momentary paralysis of the nervous mechanism, which inhibits katabolism. This, like sudden cooling of the skin, often raises the body temperature, both by increasing by reflex action the production of heat in the passive muscles and by directly limiting the heat loss.

In summing up the action of the oscillatory currents upon the body, it must be remembered that their influence on the nervous system is manifest by the absence of a sensible reaction, by anæsthesia, myasthenia, and vasomotor effects.

It has also been noticed that they cause an increase in blood-pressure, and in the number and depth of respira-

tions, as well as in the amount of oxygen absorbed and carbonic acid eliminated. The internal respiration of the tissues, or exchanges between the tissues and blood, being increased, there is a consequent increase in the amount of heat produced, and in the quantity of urine and urinary extractives eliminated by the kidneys.

CHAPTER VII.

THE EFFECTS OF HIGH FREQUENCY CURRENTS UPON MICRO-ORGANISMS.

In the preceding chapters, which treat of the physiological action of alternating currents of high frequency upon the human organism, it can be noticed that general rather than local D'Arsonvalization exerts a more marked influence upon the system. In studying the effects of the oscillatory currents upon micro-organisms and the morbific products of their life-history the position is reversed; for, while the methods of general D'Arsonvalization can, at the utmost, only effect some degree of attenuation of the virus secreted by pathogenic organisms, without directly influencing the germs themselves, local D'Arsonvalization has a more powerful action on all forms of germ life.

D'Arsonval commenced his study of the biological effects of high frequency currents with some experiments upon the yeast plant and other monocellular organisms. Finding that these could be influenced by currents of high frequency, he extended his investigations, and, with the aid of Charrin, experimentally determined the effects of the currents upon pathogenic micro-organisms. These experiments started with observations made upon the *Bacillus pyocyaneus*, cultures of this micro-organism

being submitted to auto-conduction. They found that a diminution could be noticed in the chromogenic functions of these bacilli; but this modification was not accompanied by any very special alteration in the form of the bacilli themselves, or in their pathogenic properties.

They further observed that by prolonged treatment the multiplication of the germs could be retarded.

In another series of experiments, made to determine the effects of direct applications on the same organism, it was found, by culture experiments made upon agar with bacilli submitted to this form of electrization, that the germs had, in spite of treatment, preserved their chromogenic functions intact. This difference in the results of direct and inductive applications is remarkable.

D'Arsonval himself attributes the difference to a modification of the bouillon culture medium used in the first experiment, and not to any specific action upon the bacilli themselves. Yet in the face of this explanation, he asserts that 'auto-conduction is the only procedure that assures the propagation of a current in material particles as tenuous as the microbes.'

These writers have also experimented with the toxin of diphtheria. Selecting a very virulent toxin for the purpose, they exposed it for fifteen minutes to the direct action of the currents. The method adopted was as follows:

The diphtheritic toxin was placed in a U-shaped tube in which two platinum electrodes were fitted. These electrodes were connected with opposite poles of the solenoid of high frequency. To prevent the heat engendered by the passage of the current from complicating the results

observed, it was found necessary to keep the tube in a refrigerating tank. The temperature of the toxin was thus, during the whole course of the experiment, never allowed to pass beyond 18° C. To test the product so obtained, some 2·5 c.c. were injected into three guinea-pigs, while three control animals received a similar dose of untreated toxin.

The control animals succumbed twenty, twenty-four, and twenty-six hours respectively after inoculation, while those treated by the electrized toxin did not even sicken. This investigation led on to another, made to test the immunizing effects of the electrized toxin. The three animals already alluded to, with three new control guinea-pigs, received a dose of 0·5 c.c. of untreated diphtheritic toxin. Two of the control animals died in two days after inoculation, while the third control succumbed on the third day after injection. Of those treated in the previous experiment to a preliminary dose of electrized toxin, one died four days after inoculation, the other two remaining alive and well up to the end of the ninth day.

D'Arsonval and Charrin are therefore of opinion that the electrized toxin had increased their resistance.

The publication of these experiments of D'Arsonval and Charrin led to the subject being further investigated.

Bonome Viola and Casciani succeeded in reducing the streptococcal toxin to a tenth of its original virulence. They even claim to have succeeded by their method in preparing an effective diphtherial antitoxin.

Haller, by passing the currents through a liquid in

which algæ, fungi, and bacteria were present, proved that they exert an inhibitory influence upon the development of all forms of germ life.

Dubois, of Rheims, confirmed D'Arsonval's statements concerning the attenuation of the toxins, but could not prove the slightest immunization. He also selected streptococci for his experiments. Healthy cultures of this micro-organism on liquid serum were enclosed in a parchment bag, the seams of which were closed by paraffin. This bag, which measured 6 to 8 centimetres in length by 1 centimetre in breadth, was suspended, by silken threads fastened to the extremities, in a broad-mouthed **U**-shaped tube filled with liquid serum. At either end the tube was closed by a well-fitting block of retort carbon luted with paraffin. To these discs the wires leading to the solenoid were connected. The temperature of the liquid during the whole course of the experiment was, by means of a water-bath, maintained at a uniform temperature of 20° C. He then found that, although the toxins formed had undergone a considerable attenuation, their immunizing and curative effects were nil.

In 1896 Marmier, by a series of experiments, tested the action of high frequency currents upon the toxins of diphtheria and tetanus, as well as on the venom of the cobra and viper. He found that an attenuation of their virulence was brought about by the elevation of temperature caused by the passage of the currents.

Basing his remarks on the results of his own observations, he endeavoured to controvert the statements made by D'Arsonval, who, in self-defence, maintained "that he

took every precaution to prevent all abnormal heating of the toxins." D'Arsonval and Charrin then began a new series of experiments, in which they succeeded, by means of refrigerating mixtures and experiments *in vacuo*, in keeping the temperature of the toxin, or of the soluble ferment, down to freezing-point.

These experiments yielded somewhat similar results. By control experiments Charrin was able, in certain cases, to prove a small but distinct attenuation.

D'Arsonval and Phisalix then tested the effects of high frequency upon cobra venom, which ordinarily requires to be heated in a sealed tube to a temperature well above 150° C. before it loses its virulence. In the first experiment the solution of the venom prepared by admixture with glycerine (50 to 100 parts) was submitted to the action of the currents. A very considerable attenuation of virulence was thus obtained, for a guinea-pig which received a dose of the electrized venom survived the experiment, although its temperature was for some time lowered two degrees and a very pronounced local reaction produced. A control animal which received a dose of the untreated venom succumbed to the poison in less than ten hours. At the end of six days the guinea-pig tested by electrized venom was, with another control animal, inoculated with a dose of untreated venom. It was then noticed that, while this guinea-pig died twelve hours after inoculation, the control animal succumbed in the short space of five hours thirty-five minutes. Although this result was not altogether satisfactory, it suggested to them the possibility of obtaining more positive results

by using, in place of the highly-resisting glycerine, a solution of venom in salt solution (7·5 per 1,000). The second series of experiments made with this solution was more successful. They were thus able to prove that cobra venom loses its virulence when submitted to electrization by high frequency.

In the experiments above referred to it can be noticed that the effects of general D'Arsonvalization, both by means of the direct or inductive methods of application, are very limited. It is evident that high frequency currents do not exert any specific influence upon micro-organisms, although they appear, by modifying the chemical constitution of the culture media, to somewhat injure their development. The results of experiments on toxins and cobra venom have shown that the currents are capable of producing certain subtle modifications in their chemical composition which, by attenuating their virulence, increase the natural resistance of the animals experimented upon to more potent doses of the same poison. It is, moreover, true, as D'Arsonval remarks, that the attenuation of the toxin is in no wise constant, as certain toxins succeed in perfectly escaping reduction, while even in the same toxin the age, the production, and mode of preparation, are among the conditions that serve to diversify the results.

Again, opinions are divided as to the cause of the attenuation of the virus. Marinier attributes it to the heat engendered by the passage of the currents; but this D'Arsonval denies, on the dual grounds that in the greater part of his experiments special precautions were taken to prevent any

rise of temperature in the liquid, and that electrization can effect, as Phisalix's experiments prove, an attenuation of the virulence of cobra venom, a result which, under ordinary circumstances, can only be effected by a temperature much above 150° C. He ascribes it to phenomena of the electrolytic order, but says that, while the passage of the currents gives rise to very rapidly alternating interpolar molecular combinations and decompositions, it is not accompanied by any disengagement of free products capable of chemically acting upon the toxins. Marinier, Reus, Sailer, and Papiermeister deny the correctness of this statement of D'Arsonval. Marinier believes that by the electrolytical decomposition of common salt contained in the nutritive media, a subchloride of sodium is produced, which destroys the toxins. Reus is of opinion that the passage of the current results in a dissolution and rearrangement of the molecules of toxic substances, which reduces its virulence. Sailer and Papiermeister hold somewhat similar views, except that they believe that, by oxidation of a part of the nitrogen of the cultivating media, nitrous compounds are formed, which react upon the toxins and produce an attenuation.

The effects of local applications upon micro-organisms have been studied by Doumer and Oudin, by Freund, by Sailer and Papiermeister, and also by Foulerton and Kellas.

Doumer and Oudin experimented with the Klebs-Loeffler bacillus and also that of Koch. The currents employed were furnished by a resonator of the usual type. In the first series of experiments they tested the influence of currents circulating in a short spiral connected with

the free terminal of the resonator on cultures contained in a tube, round which the wire was wound. These cultivation experiments gave negative results. They next tried the effect of connecting, by means of a platinum wire, the culture medium to earth. This gave similar results. Then they varied the experiment by connecting the spiral coil to earth and the platinum wire to the resonator, without effecting any modification. In their last experiment they inoculated a platinum wire with a healthy culture of the micro-organisms under observation, and connected it with the free terminal of the resonator for ten minutes.

All culture experiments made with these electrized micro-organisms yielded positive results, from which they conclude that the effluve of resonance exerts no bactericidal effect upon micro-organisms. Freund, on the other hand, clearly proves that the discharge of high frequency has a decided action upon all forms of germ life, for it not only prevents their development, but can also destroy (according to the conditions of the experiment) well-developed colonies of the *Staphylococcus pyogenes aureus*, and the bacilli of anthrax, typhus, tubercle, diphtheria, and favus.

Sailer and Papiermeister have experimented with yeast-plants, various forms of fungi, the *Bacillus pyocyaneus* and *B. prodigiosus*, as well as the micro-organisms of tubercle, anthrax, diphtheria, typhoid, and specific urethritis (gonococci). They employed the effluve derived from D'Arsonval's apparatus of high tension. They found that the following conditions affected the propagation of micro-organisms, and could, under certain circumstance, destroy them :

(*a*) *The Density of the Currents employed.*—Currents of greater density proved very effectual in rendering the medium of culture perfectly sterile.

(*b*) *The Character of the Discharge.*—While a discharge of sparks destroyed the colonies against which they were directed, their effect upon surrounding colonies was nil. On the other hand, the more gentle and readily diffused effluve hindered the development of all the colonies, without effecting their destruction.

(*c*) *The Time of Exposure.*—The more prolonged the duration of treatment, the more effectual did it prove. For instance, while effluvation for ten minutes hindered the development of the colonies, a prolongation of treatment for thirty minutes utterly destroyed them.

(*d*) *The Distance between the Electrode and Culture Surface.*—The closer these two were approximated, the more successful were the results obtained.

(*e*) *Connection to Earth of the Culture.*—This intensified the destructive effects of the discharge upon the micro-organisms.

(*f*) *Double Effluvation* proved still more effective than simple connection to earth.

In summing up their experiments they say: 'We are convinced that effluvation, rather than auto-conduction, is *par excellence* the mode of treatment to be adopted in the treatment of diseases of bacterial origin; for, while the methods of general D'Arsonvalization, as D'Arsonval has proved, only influence the virulence of the toxins produced by the micro-organisms, effluvation, on the other hand, directly retards the development of the germs themselves, and often effects their destruction.'

PART III.

THE THERAPEUTICAL USES OF HIGH FREQUENCY CURRENTS.

CONTENTS OF PART III.

CHAPTER I.

INTRODUCTORY.

From the chapter dealing with the physiological properties of high frequency it is obvious that the currents are capable of exerting a considerable influence on tissue metamorphosis. As the general systemic effects are more in evidence with the methods classed together under the head of general D'Arsonvalization, it is only natural to expect that some of these methods would prove most suitable for the treatment of general diseases dependent on perverted tissue nutrition, or of local conditions which are the partial manifestations of an underlying general dyscrasia.

Thus it is that general D'Arsonvalization has been employed in the treatment of gout, rheumatism, obesity, diabetes, and in the neuro-central and peripheral manifestations of these diseases. Again, as the anæsthetic effects of the currents are most prominently brought forward by local and direct applications, it is evident that these methods can with advantage be employed in overcoming pain and discomfort arising from exaggerated nervous sensibility. This at once suggests their employment in pruritus, muscular rheumatism, neuralgia, pleurodynia, sphincteralgia, and a host of other local affections

in which pain is a very prominent symptom. The revulsive effect of local applications can be turned to account in the treatment of deep-seated congestions, as well as to stimulate to more healthy action chronic local conditions arising from deficient or perverted tissue nutrition. So, similarly, can the myasthenic influence of the currents be rendered useful in overcoming muscular spasm in those diseases in which it is a prominent symptom, more especially when due to nervous causes. This immediately connects itself with asthma, vaginismus, anal spasm, as well as with stomachic dilatation dependant on pyloric spasm such as accompanies hyperacid conditions of the contents of the stomach.

The action of the currents upon the vasomotor nervous system can be directed against diseases arising from the functional aberrations of the general sympathetic system. So also can effluvation of the spine be employed to raise blood-pressure in all morbid and depressed states in which such a procedure is indicated; while the tonic effects of the discharge on contractile structures, more especially the smooth muscular fibres, can be brought to influence the hollow viscera and glandular organs, and excite them to a more healthy action, such as in dilatations of the stomach and intestines, constipation, bronchiectasis, chronic, splenic, and hepatic enlargements, etc. The effect of local discharges on germ life suggests their utility in both general and local diseases of bacillary origin. So likewise does the advantage to be derived from cataphoresic treatment bring to mind a multitude of diseases that can be benefited by local medication.

CHAPTER II.

THE VALUE OF HIGH FREQUENCY CURRENTS IN CERTAIN SURGICAL CONDITIONS.

Sprains.—The pain and swelling caused by the effusion of blood and serum into the cellular tissues around the seat of injury may be greatly lessened by the action of high frequency currents, and a speedy cure may be assured.

When the injury is an old one, and the part is indurated and adhesions have formed, it will be necessary to prolong the treatment for some time. The proper procedure is condensation, while the part is gently massaged; this should be continued for about ten minutes, to be followed by another ten minutes with the effluve.

Synovitis, both acute and chronic, of the sheaths of tendons should be treated in the same way.

In all Joint Inflammations not characterized by the presence of pus, or of a malignant or gonorrhœal nature, the application of condensation combined with massage will produce a marked improvement in a comparatively short time. In all these cases an application of the effluve should also be used.

Dislocation after Reduction may be treated in the same way as sprains. If the reduction has taken place soon after

the accident, the application of the effluve from the brush electrode will be sufficient. The application will greatly relieve the pain, and will cause the effusion of blood and serum in the cellular tissues around the joint to be more rapidly absorbed.

It follows from what has been said that all effusions of blood and serum due to injury are absorbed more rapidly when treated with high frequency currents. If a bruise be treated immediately after the accident, no ecchymosis will appear; but if the characteristic black and blue has made its appearance, applications of the brush discharge will cause its rapid absorption.

Delayed Osseous Union.—Dr. H. E. Gamlen, in the *Archives of the Roentgen Ray*, February, 1906, reports a case where the administration of high frequency currents promoted osseous union. He states: "Three years ago the patient sustained a severe wrench from the machinery of a locomotive, which resulted in both bones of the forearm being fractured. The bones were immediately set at a local hospital. Six weeks after the accident it was found there was no bony union. The man was sent to a specialist, who took a radiograph, which clearly showed absence of union. Another specialist recommended change of air, in the hope that if the constitution were improved the fragments would have a better chance of uniting. Although the patient followed this advice, there was still no success. The patient was subsequently operated on at an infirmary, the bones being wired. There was, however, still no union, and a later operation also resulted in failure. He next went to London, where

a private practitioner and a surgeon of one of the large hospitals advised further operation. He then visited me, and a radiograph was taken. In order to strengthen the system I administered a series of high frequency sittings, after which I performed an operation. The result was a bony union, which continued for several months, and gave the man a useful arm. At the end of this time he sustained a further accident, which resulted in another fracture. It may be assumed that the high frequency currents had stimulated the constitution to an extent which made the operation more effective than would otherwise have been the case."

CHAPTER III.

TUBERCULOSIS.

Phthisis.—In his book on "High Frequency Currents," Mr. Chisholm Williams writes: "There is reason to believe that the currents act in these cases in the following manner:

"Firstly, on the tubercle bacilli themselves, by making them pursue the same course as if they were under the X rays. According to the experiments of Drs. Forbes Ross and Norris Wolfenden, in their paper on the 'Effects produced in Cultures of Tubercle Bacilli by Exposure to the Influence of an X-ray Tube' (*Archives of the Roentgen Ray*, August, 1900), they observe that the bacilli rapidly increase in numbers, and have a tendency to form clumps, then get small in numbers and shape and take the microscopical stains very readily, but are pale in colour. They say, in conclusion: 'There is not the smallest doubt that X rays stimulate them to excessive overgrowth, and only affect them adversely by attenuation from overgrowth.'

"In my experience much the same process goes on under the high frequency treatment. The tubercle bacilli, which are usually present in fair numbers, quickly begin

to increase, and after a few applications are greatly increased; they soon, however, form clumps and get misshapen, short and stumpy, and generally curved, and take the stain far more readily than before. After a time they begin to decrease in numbers, and later, when the patient is obviously getting better in every respect, they may cease entirely, and may appear in the sputum after weeks of absence.

"Secondly, the effects of the currents of high frequency on the individual cells of the body. We judge this by the appetite and digestive powers increasing, and the patient's gain in weight. The general improvement of the body-cells probably makes them more resistent to the inroads of the tubercle bacilli; but whether the lowering of the tubercle's vitality, or a raising of the body-cells' resisting power, or a combination of both is at work, for our purpose matters little. In the majority of these cases the leucocytes were greatly increased in numbers during a course of the treatment.

"In some cases the temperature is the first thing affected. Presuming that the daily variation had been of about 3° between the evening rise and the morning fall, either after the first application, or, at most, after the third (consecutive days), the evening rise should be higher and the morning fall less.

"On examining the affected area, we find the physical signs at first increased: thus more coarse râles of louder and of a greater number could be found; the expectoration becomes larger in amount, and the cough more frequent and easier. After a few applications, generally

when given locally, the patient often complains of pain or an uncomfortable feeling over the affected part. This, as a rule, passes off after a couple of weeks' treatment, and is never severe if due attention be paid to the length of time and number of the applications. A slight amount of pain over the affected area in severe cases is often noted from the general methods.

"When the temperature has been raised by the treatment, the patient, of course, may feel rather worse—*i.e.*, lassitude, and the sweats on the fall of the fever are sometimes large in amount; also during this period the body-weight may decrease, or, at all events, remain stationary. I found this in many cases where the fever increased, and in spite of the patient taking presumably a much more nutritious diet, still a slight weekly loss was observed. Some cases will react to the influence of the high frequency currents within twenty-four hours; others may take a few days.

"The more severe the case the more quickly does the reaction take place. However much the temperature rises, it will generally be found down to or at the patient's usual normal within forty-eight hours, so that the dose can be readily regulated, and the patient only given as much as he can comfortably bear. When the patient can be exposed to the currents for over half an hour daily for one week, and it is found that during the whole period the temperature remains steady at normal and subnormal, we may safely predict that the disease is, to say the least of it, arrested.

"I am strongly of opinion that the application of high

frequency currents will greatly swell the number of cures. It is a remedy that should only be administered by medical men, as it needs as much care as any other therapeutic agent."

The method of treatment is condensation for about ten minutes, followed by brush-discharge from the effluve to the front of the chest over the diseased area, the other hand of the operator being at the same time placed at the back of the chest. The large electrode made by Schall, mentioned in a previous chapter, may also be employed in cases of pulmonary disease.

Tuberculous Glands.—Dr. Clarence L. Coon, of Syracuse, New York, reports the following cases where the application of high frequency currents has given relief in this condition:*

Case I.—Boy, aged seven; no immediate tuberculous family history. The patient has always been very nervous and anæmic, and has required tonics most of the time, and these have included cod-liver oil in various emulsions and pure arsenic in large doses, iron, strychnine, etc. About April 1, 1904, swelling of both sides of the neck occurred, and increased rapidly in size; his mother thought that it was mumps. When the patient was seen about three weeks later the cervical glands of both sides were much enlarged, the largest being along the anterior margin of the sterno-mastoid, and deep seated. The largest were fully an inch in diameter, and quite tender on pressure. The chain of superficial glands along the posterior margin of the sterno-mastoid were all enlarged,

* *Archives of the Roentgen Ray*, June, 1905.

and scattered over both sides of the neck were many large and tender glands. Besides the cervical ones, enlarged glands were met with in the groin and Scarpa's triangle; the right lung was slightly high-pitched, and a heart murmur, probably hæmic, present.

Blood examination: Hæmoglobin, 61 per cent.; white cells, 13,000. Diagnosis, tuberculous condition. Prognosis unfavourable. In addition to the usual treatment, high frequency currents were first used on May 2, 1904.

May 8, swelling in neck was reduced in size; general condition improved.

May 18, improvement in patient's condition is quite marvellous.

Treatments were continued every other day until July 7, when the patient went to the country. At this time the enlarged glands, except two of the very largest, had disappeared; the two remaining were much reduced in size, and were difficult to locate on palpation. The cough had almost ceased, and the patient now ate and slept well, and had a healthy appearance.

On August 23 treatments were resumed and continued at irregular intervals; there had been no retrograde changes during the summer.

On October 6 there were no enlarged glands on the left side of the neck, and only one very small, deep-seated, on the other side.

Since July 1 the patient's general condition has been much better than at any previous time during his life; he has increased in stature, and many of the old nervous

symptoms are entirely absent. Little change was made in the medicinal treatment.

Case II.—Recurrent tuberculous adenitis. The patient was a high-school girl. About four years ago she had had a radical operation for removal of cervical glands, since which time there have been frequent enlargements, which soon caseate and suppurate, and, after opening, are very slow to heal; consequently there have been sinuses in the neck most of the time.

On September 1, 1903, there was present a narrow sinus about an inch in depth in the right side of the neck; after four treatments this had entirely healed. She continued treatments at irregular intervals during the winter, and until April, 1904. As soon as a gland became a little enlarged and tender, she would receive two or three treatments, and in this way she remained free from active trouble.

Scrofulous Ulcers of the Legs (Bazin's Disease).—Dr. W. F. Somerville, in the *British Medical Journal*, February 4, 1905, gives the following particulars of a case of this kind treated by him with high frequency currents:

"The patient, a young lady aged sixteen, who had spent the greater part of her life in Eastern Europe, was brought to me by Dr. Alexander Thomson, of Glasgow, early in January, 1904. She was tall, of dark complexion, and somewhat phlegmatic disposition. With the exception of a number of ulcers on her left leg, and some evidence of anæmia, she appeared to be free from definite signs of disease. There was, however, a degree of coldness of the extremities, and at various times, it was said, she had

suffered from enlargement of the glands in the sub-maxillary region—facts which may be quoted in favour of the diagnosis here suggested.

"Neither in the family history nor in the physiognomy of the patient was there anything to suggest the possibility of a syphilitic taint.

"There is no history of tubercle in the family.

"When the young lady came to me I found on the anterior aspect of the left leg seven punched-out ulcers, ranging in size from a threepenny-bit to a florin.

"The ulcers had undermined, irregular edges, resembling markedly the ulcers produced by specific disease, to which, as Mr. Hutchinson points out, cases of Bazin's malady are apt to be referred. The skin in the immediate neighbourhood of each ulcer had the dark red 'violaceous' character described by Bazin, and was free from irritability and tenderness. The high frequency currents were first applied by me on January 12, 1904, and were continued till March 28, 1904, forty-one applications in all being employed. The patient reclined for about eight minutes on the condensation couch; afterwards the limb was treated by the spray effluve, and also with a flat glass electrode of high vacuum connected with the top of the Oudin-Dean resonator. Very shortly after treatment was commenced the ulcers began to take on a more healthy appearance; they gradually filled up, and the usual healing line was soon noticeable, until finally they were covered entirely with healthy skin.

"I saw the patient at the end of January of this year, when I found the ulcers perfectly healed, the skin of the

limb quite smooth and free from induration, and was surprised to learn that a short time previously the young lady had walked no less than thirty miles in one day without any evil effect, and had been climbing hills during the summer holidays."

Tubercular Bursitis and Ganglion.—Dr. Clarence A. Wright, in the *Archives of the Roentgen Ray*, June, 1905, writes: "These diseases, when treated, rapidly yield to the effluve of high frequency.

"*Technique.*—In all tubercular affections characterized by exudation, the effluve of high frequency, judiciously applied, has been instrumental in promoting absorption. The same method of application can be made use of in tubercular peritonitis, in which infection of the mesenteric glands plays an active part; but if diarrhœa or undue irritability of the intestinal tract be present, derivation methods are to be preferred.

"*Results.*—Rapid absorption of the effused fluid generally takes place after the sixth to tenth application, but the sessions require to be continued at longer intervals for some time after, as there is always in these diseases a tendency to relapse.

"*Illustrative Cases.*—The subjoined cases, which are selected from those treated by Sailer and Papiermeister, will exemplify the results obtainable by vibratory treatment in these conditions:

"O. R., aged eighteen years, housemaid, had for the past four years been suffering from tubercular hydrops of the left knee, for which she had been treated by blisters, iodine, iodide of lead, mercury applications, and the elastic

bandage, without any permanent improvement. She was treated from July 6 to 31, 1899, by the effluve of high frequency. The effusion in the joint rapidly disappeared. She came again on October 2, as the swelling, owing to a fall down a short flight of stairs, had returned. She now had ten further sessions of effluvation, after which she expressed herself as cured. At our request she called in August, 1900, when it was noticed that the joint was perfectly natural and free from all sign of disease. During the interval there had been no sign of relapse or recurrence of the swelling.

"C. A., aged thirty-four, a layer of mosaic flooring, whose vocation necessitated long-continued kneeling, had developed a large, soft, fluctuating tumour, evidently an enlarged bursa, upon the right knee. The disease was very chronic, and, in spite of blistering with strong iodine, aspiration, and well-applied pressure with an indiarubber bandage, continued to recur at short intervals.

"When he applied to me for treatment, the tumour was of the size of a Tangerine orange. Its coats were slightly thickened. A crackling sensation was noticed on manipulation. Local applications of the effluve from an Oudin's resonator were daily resorted to. Treatment commenced on August 9, 1898, and was continued without intermission up to September 10. During this time he had received twenty-eight applications of five minutes' duration (500 milliampères). On the cessation of treatment no trace of swelling could be noticed.

"He visited me on February 7 and August 23, 1899, on

both of which occasions he was able to report satisfactorily, as he had not experienced the slightest relapse, in spite of long hours of overwork.

"J. B. C., aged twenty-four years, machinist, presented herself for treatment on September 7, 1898, complaining of a swelling on the dorsum of the right foot. Examination of the part showed that she was suffering from a compound ganglion, which implicated most of the anterior tendons. The tumour, which was irregular in form, had attained to the size of a mandarin orange. The sheath of the tendons was thickened as well as dilated, and a crackling sensation was communicated to the hand on manipulation. The effluve of high frequency was directed upon the tumour for eight to ten minutes four times a week. After twenty-six applications a complete cure was established, which has now been maintained for over two years without relapse."

CHAPTER IV.

GENERAL DISEASES.

It is usual, under the head of "General Diseases," to include the intoxications or spontaneous toxæmias, which, in the absence of more definite information as to their cause, are generally referred to aberrations in the normal nutritive exchanges of the tissues. It is known that, even in health, the metabolic processes produce certain noxious substances in small quantities. These are harmless, either by reason of their rapid elimination, or by being brought into combination with other bodies which destroy their virulence. It is obvious, therefore, that, apart from the toxæmia due to bacterial poison, there are certain antitoxic effects due to the absorption of chemical substances elaborated in or by the tissues themselves. These may be either normal metabolic products, which, by overproduction or deficient elimination, are detrimental to health, or abnormal metabolic substances, which require further elaboration to fit them for elimination from the body.

Acute Rheumatism.—Although acute articular rheumatism is not itself very amenable to treatment by high frequency (except by the cataphoresic method), there are

many of its sequelæ, which retard convalescence, that can be speedily removed by applications of this form of electrical energy. For instance, there is anæmia, generally well marked and persistent; insomnia, often a troublesome symptom to combat; tendinous and aponeurotic contractures, tending to interfere with the movement of the joints, and to produce deformities; and, lastly, the muscular atrophy attendant on prolonged disease. All these are very amenable to treatment by vibratory electrization.

Subacute Rheumatism.—It is natural to suppose that this disease, being a malady of nutrition, although arising from an acute perversion of the metabolic processes, will be more amenable to treatment. Clinical observations have proved that these assumptions are correct.

Apostoli and Laquerriere, in referring to the subject, say "that in the subacute forms one can employ the application in moderation. At first, the intensity and duration of the sessions require to be carefully watched, so that the slightest symptoms of intolerance will be respected as the criterion which determines the suspension of electrical treatment. If an amelioration, however slight, at first is manifest, and progressively increases, there is need to persevere and continue the same treatment."

Alexis Cæsare declares that, from careful observation of several cases of this nature that have come under his notice, the best indications to follow with regard to treatment are "its effects on the febrile reaction, pain, and sleep. If they are improved by treatment, then by all

means persevere; if, on the contrary, these symptoms are aggravated, the applications must be abandoned, or their intensity and duration decreased." Maslin says that he has been uniformly successful in all cases treated by "conduction combined with the brine-pack on alternate days." He, however, uses in addition, internally, natural mineral waters. Reus commends the use of auto-conduction cautiously pushed, falling back upon cataphoresic treatment on the least untoward manifestation. He also combines treatment with the free administration of mineral waters, more especially those of the slightly alkaline group.

Chronic Rheumatism.—It is in the treatment of these cases that vibratory electrization has been productive of the best results. Apostoli and Berlioz note, as one result in treatment, an improvement in diuresis and in the elimination of urinary extractives, the outcome of the increased organic combustion. They have also noticed a general improvement in the condition of the patients. "The movements become more free, the limbs more supple, rendering walking much easier. The pains, nevertheless, only diminish more or less slowly, although a definite symptomatic cure can eventually be obtained under the influence of high frequency currents."

Dr. Holcomb Burch, of Baldwinsville, New York, in a paper read in May, 1903, before the Syracuse Academy of Medicine, remarks: "My success in the treatment of rheumatism by these means has been satisfactory. During the past year I have employed these methods in the treatment of six cases of articular rheumatism. Four of these cases were subacute, two involving the knee,

one the ankle, and the other the wrist-joint. Three of these patients received great benefit from the treatment, each of them making rapid recoveries. The fourth was of gonorrhœal origin, and was not appreciably benefited. In the two remaining chronic cases one involved the wrist and the other the knee joints. Both of these cases responded to the treatment, although a longer time was required to effect a cure than was demanded in the treatment of the subacute cases."

Rheumatoid Arthritis.—This especial and peculiar disease, which is by many believed to be referable to a lesion of the spinal cord set up by peripheral irritation, may be greatly benefited by high frequency currents. The method practised by the author is condensation combined with massage of the affected part. A lady in whose right hand and arm were extensive indications of this disease, after twenty applications was so improved that further treatment was unnecessary.

The following case was treated with condensation combined with local massage for ten minutes, followed by application of the brush discharge.

The account of the case is given in the patient's own words:

"About eighteen months ago I felt a slight strain, so slight that I took no notice of it, thinking it would pass off, as strains often do. However, after some months, as it did not improve, but rather grew worse, I spoke to a doctor, who told me to paint it with iodine twice a day. This I did for a month with no result. I then showed it to another doctor, who gave me seven blisters, which

I applied round the joint; he also gave me some medicine. This treatment also did no good. I had to give up my archery and needlework, for I could not hold my work. I had also to give up playing whist, etc., for I could not hold the cards without great pain. I then went to stay in the country, thinking that change might improve my health, also my thumb; but there was no improvement. I then consulted a third doctor, who said that the only thing to do was to go to Woodhall Spa; that it was a serious case, as the muscles were withering. I went to Woodhall, and consulted the doctor there; he ordered me baths three times a week, and on the other three days hot steam for my hand and massage afterwards. Under this treatment my general health was much improved, but there was no improvement in my hand; it was very difficult for me even to dress myself. Now chance helped me, for I went to Twickenham with a friend, and was shown the high frequency treatment. I then asked the doctor if he thought there was any chance of electricity doing my thumb any good. He examined it, and said that he thought if anything would cure me electricity would. Since then I have been to him twice a week regularly, and I am thankful to say that the muscles have regained their use and strength, and the pain has gone. I can now sew for a time without any pain, and dress myself without thinking of how to do so, and I have returned to the wear of kid gloves, which I could not put on for nearly a year. The doctor also promised to allow me to return to the archery field, and I am sure I shall be able to. I also play Bridge without any discomfort, and

life altogether is again worth living, as I am steadily improving under his treatment, which I have had for three months."

Lumbago.—In this and other forms of muscular rheumatism the application of high frequency currents is of great value. The pain and stiffness is diminished from the first, and the whole course of the attack very much shortened.

Sciatica.—Condensation combined with massage, followed by the application of the large electrode for about ten minutes daily, will cut short an attack of this malady.

In a paper read before the British Electro-therapeutical Society in April, 1904, Dr. Somerville states: "In the first place I will quote some of my experiences in dealing with patients suffering from sciatic pain. In such cases it is necessary to satisfy one's self that the pain is a simple neuralgia of the sciatic nerve, and does not depend upon adhesions, the result of a perineuritis. The latter instances demand operation, for the purpose of separating the adhesions, which, by dragging on the nerve, cause pain.

"Simple neuralgias, on the other hand, are readily amenable to high frequency treatment, and in my experience the cure is almost invariably a permanent one. My first case was that of a farmer, weighing about 17 stone, who had suffered from sciatica of the right lower limb for six months. The pain was present not only when he moved, but even while he was at rest. Here I felt I had to deal with a case of pure neuralgia of the nerve, un-

accompanied by adhesions. He required only eight applications to cure him of his pain. I could then place him in all positions capable of putting the nerve on the stretch without any discomfort to himself. The patient was treated by me in September, 1902.

"I have seen him occasionally since, when he confidently affirmed that he was suffering no pain. My last interview with him occurred last month, eighteen months after treatment, when I was happy to find that the pain had never returned, though in his work as a farmer he had been exposed to all kinds of weather. His own belief in the benefit he derived took a very practical turn, for he was the means of sending me several patients from his village.

"One of these was a mason, fifty years of age, who informed me that he had been subject to frequent attacks of pain in the lumbar region, due, as he supposed, to a twist, or 'rack,' as we call it in Scotland, while lifting stones. This statement was corroborated by his own doctor. The patient presented himself for treatment in November, 1903, and received five applications, which relieved him of all pain. He was last seen by me a month ago, four months after he had been treated, when he told me in grateful terms that he had had no return of pain.

"Another case of sciatica accompanied by lumbar pains and stiffness at the knee-joints was that of a lady weighing over 13 stone, who was treated by me in June, 1903. After a short course the pain over the sciatic nerve and gluteal region disappeared. The knees became much less painful, and she was able to go up and down stairs

and rise from her chair without any pain, and to play golf in the autumn. I heard of her a few weeks ago, and was gratified to learn that the benefit derived nine months previously still remained."

Dr. Coon of Syracuse also records the following case :* "A woman has for several years been troubled with rheumatic pains in various parts of the body; the most constant painful area has been in the lower lumbar and sacral region, with pain radiating down each sciatic nerve. She has taken all the anti-rheumatic remedies, salicylates, and other alkalies. On April 30, 1904, she had not been free from pain in her back and thighs for several weeks. High frequency treatment was begun on this date, and up to May 23 she had nine treatments; she was then free from trouble, and was doing more housework than she had been able to do for a long time. An occasional treatment was given between May 23 and June 27. On October 12 she reported that she had remained very well all the summer, and had only had an occasional twinge of the old trouble."

Gout.—As in rheumatism, it may be at once said that acute attacks of gout are unsuitable for treatment by high frequency currents; but in cases of chronic gout it is the experience of many observers that this treatment is extremely beneficial. Care should be taken to cease the treatment if there should be any indication of an acute attack.

High frequency currents are also of great service in cases of gastric neurasthenia attended with defective

* *Archives of the Roentgen Ray*, June, 1905.

metabolism. They are especially valuable in the neurasthenia of gout, and in cases where the patient takes too little exercise. In these cases, in addition to general condensation, the large electrode should be applied to the epigastrium for about ten minutes, followed by condensation for another ten minutes. Applications should be given daily for a week or two.

Diabetes. — In this disease, although high frequency currents will not effect a permanent cure, yet by their aid the general health may be greatly improved, and the amount of sugar passed in the urine considerably diminished.

Dr. Gamlen, in the *Archives of the Roentgen Ray* for February, 1906, writes: "High frequency currents are decidedly beneficial in cases of diabetes. They not only improve the metabolism of the system in a general way, but actually decrease a certain quantity of sugar formation. In one case which had been regarded as hopeless I gave high frequency sittings, lasting ten to fifteen minutes, twice a day. At the same time I carefully observed the effect produced. The patient was weighed at intervals, and after three weeks' treatment an increase of 5 pounds was recorded. Three specimens of urine were sent to the Clinical Research Association of London. The first report showed a proportion of 93·3 parts per 1,000; a week later the quantity was reduced to 83·7 parts per 1,000; and finally the average was as low as 59·5 parts per 1,000. These figures clearly indicate a decided improvement. When the patient consulted me he was already taking medicine and conforming to a prescribed

diet. I did not feel justified in changing these precautionary measures, but the progress made was of such a striking nature as to leave no doubt that the high frequency currents were helpful to the ordinary form of treatment. Unfortunately, the patient did not continue to attend, and as I have not been afforded the opportunity of treating other cases in a similar way, it is impossible to affirm anything which would induce me to be emphatic."

Obesity.—Concerning this condition Dr. C. W. Allen, of New York, writes: "There are a number of very encouraging results reported in the treatment of this condition. Boinet and Caillol de Poncy* speak of a number of patients treated by auto-conduction, in whom the average loss of weight amounted to as much as 14 pounds a month. Williams reports one instance where the girth of a patient was reduced 4 inches within nine weeks, practically without loss of weight. He thinks that the increase of the digestive functions and the increase in the elimination of the phosphates and urates is mainly responsible for the beneficial results.

"Moutier claims that the high frequency currents do not bring about a diminution in weight, but that they decrease the body volume by making it more dense.

"Foreau saw no result in obesity, but he noticed that patients treated with the high frequency currents tolerated the thyroid cure better. As early as 1897, at the Moscow Congress, Apostoli and Berlioz pointed out the influence which could be exerted on obesity. When this condition is associated with diabetes and arthritism the chances of

* *Soc. de Biologie*, July 31, 1897.

benefit are greater. Auto-conduction or condensation is the method recommended. Heart disease furnishes a contra-indication here as well as in other conditions."

Anæmia and Chlorosis. — Cases of this kind show a marked improvement when treated with the condensation method.

The hæmoglobin of the red corpuscles quickly increases in quantity and the cells resume their normal appearance. If there should be constipation, as there generally is, the abdomen should be well massaged during the sitting.

CHAPTER V.

DISEASES OF THE NERVOUS SYSTEM.

Headache.—High frequency currents are of great value in cases of persistent headache of nervous origin, although it may have lasted a considerable time.

A gentleman who had suffered from intense headache for eight months was quite cured after six applications. The method employed was that of condensation, with light massage of the forehead.

Dr. Somerville, on this topic, remarks:* "It is very gratifying, both to patient and doctor, to be able sometimes to dispel a nervous headache, and this pleasant experience, by means of high frequency currents, is of frequent occurrence. Even in cases of persistent headache, lasting more or less for years, the effect of the high frequency currents is sometimes remarkable. A lady of over thirty, the mother of several children, was sent to me in November, 1903, by Dr. Dick, of Dumbreck, suffering from headache of many years' duration. For the past four years headache had been almost constant. She suffered also from sleeplessness, which may have been the cause or effect of the headache. About twenty-four appli-

* *Medical Electrology and Radiology*, May, 1904.

cations of high frequency currents were required to remove the headaches. Sleep returned to the extent of permitting the lady to sleep for eight hours at a stretch. Her hair, too, which had previously been coming out, showed new growth, and the change in her facial expression was most noticeable. Here the cure has been permanent, and though a pregnancy and the nursing of sick children have tried her nerve energy, yet she still remains free from headache, and, with few exceptions, enjoys a good night's sleep."

Insomnia.—When patients are being treated with high frequency, it is almost invariably found that they sleep better at night, although they may not be subject to insomnia. When this condition is present, however, high frequency currents are valuable for producing a natural sleep, which is unattended by any of the uncomfortable symptoms which accompany sleep set up by drugs.

Dr. Somerville, as regards insomnia, states:* "It is well known that hypnotics to produce habitual sleep have to be continuously prescribed, sometimes in increasing doses, and, further, that no hypnotic can be taken for any length of time without giving rise to unpleasant consequences. By electricity, on the other hand, the sleep that is produced resembles that of childhood, and it is unaccompanied by any headache, disturbance of digestion, constipation, or nervousness, all of which symptoms we are accustomed to meet with in those for whom the usual sleep-producing drugs have been prescribed. The sleep which electricity gives rise to is not only sound, but

* "High Frequency in Insomnia," by W. F. Somerville, 1905.

decidedly refreshing, and, still further, not only do the high frequency currents induce sleep, but, as we who employ this form of electricity are well aware, they improve the tone of the system to such an extent that our patients are better fitted to resist and to overcome the evil influence of business, educational, or domestic cares and anxieties.

"The explanation of the influence of high frequency currents in producing sleep in the human subject I am not prepared to state; indeed, I question if anyone can at present satisfactorily explain how these currents exercise their hypnotic effects. Still, when it is remembered that the high frequency currents act on the vasomotor system and give rise by inhibition to dilatation of the bloodvessels throughout the body, a condition clearly manifested in the sensation of warmth experienced for several hours in the extremities and on the surface of the body generally, one is led to conclude that a corresponding anæmia of the brain is caused which may produce sleep.

"I may now refer to my own experience in the treatment of insomnia. While comparatively few patients have sought my assistance suffering purely from sleeplessness, a great many who have come to me for treatment for various diseases have mentioned that sleeplessness was a prominent feature in their case. I think I may safely say that in two cases only have I met with complete failure; all the others have benefited to a greater or less degree. I am frequently told by patients who, suffering from various ailments present themselves for high frequency treatment, that after the first visit they have been so over-

come with sleep that they have had to lie down for one or two hours in the afternoon. The more severe cases of insomnia, however, do not, as a rule, respond until they have had about three weeks' daily treatment."

Neuritis.—Dr. Coon reports the following cases, treated by local applications of vacuum electrodes:

"CASE I.*—A woman who had exceedingly painful neuritis of the left upper extremity with anæsthesia of the index-finger. For several weeks she had been unable to sleep without an opiate. There was no eruption upon the skin; she complained only of the severe pain and the clumsiness of the index-finger. All the usual remedies had been tried with little or no relief, and the condition was such that the actual cautery was considered as a means of obtaining relief. The high frequency treatment commenced in the latter part of October, 1903. The first two or three applications seemed to intensify the pain, but following the fourth there was rapid improvement; and on November 20 recovery was complete, the numbness of the index-finger being the last to clear up. For ten months after the final treatment there has not been any further trouble.

"CASE II.—Woman, aged sixty-four, who for fifteen years had pain in right arm and shoulder, and for several months the same kind of pain in the left arm and shoulder. The pain was not severe, but was always present; in front of the internal condyle of each arm were tumours about the size of a hen's egg, which felt soft and 'crawley' on palpation, and pressure caused pain to radiate down the fore-

* *Archives of the Roentgen Ray*, June, 1905.

arm. Near the middle of the anterior surface of each forearm were smaller similar tumours. The patient said she had been treated for rheumatism by medication, hot air, etc., without a particle of relief. The diagnosis was chronic neuritis with neuromas. Only five applications were made, on account of the distance she had to travel. At the time of the last treatment she was freer from pain than she had been for years, and examination showed the neuromas to be markedly reduced in size. She expected to continue electric treatment in a neighbouring city.

"CASE III.—Woman, aged thirty-three, who had disordered sensations in the lower cervical and upper dorsal region. For about five years she had had trouble in this region. At times she said that this area felt as though it had been bruised; it was not distinctly painful, except on pressure. At other times she felt as though a cake of ice was laid against the skin. It was very annoying, and she had become very nervous worrying about it. Occasionally the arms and forearms would feel numb and prickly. Examination of the spine showed an area of tenderness on pressure, extending from the last cervical to the seventh dorsal vertebra, and was most pronounced at the second dorsal vertebra; surrounding this area for a distance of about 2 inches on either side was a slight erythema. She had tried a variety of treatments, including mild counter-irritation, without relief. After the second high frequency application she felt much better, and twelve treatments at somewhat irregular intervals, extending over a period of eight weeks, accomplished a cure.

"CASE IV.—Woman, aged about twenty-five, who for

about six weeks had suffered from pains in various parts of the body; these were very severe. About twenty-four hours after the onset of the pain an eruption appeared on the skin over the painful area. Pain continued, and affected various parts of the body, including the buttocks, thighs, thorax, and upper extremities. When first seen on May 8, 1904, she complained of pain in the left shoulder and arm, which had been present for two days. Examination showed a herpetiform eruption, most marked down the inner side of arm and forearm; bright red, macular, very slightly raised, discrete, and a little evidence of vesiculation. When the spots first appeared there was considerable itching. This subsided when the eruption had reached its height. There were only a few macules on the shoulder and above the breast; the inner side of the arm was well covered, and on the forearm five spots were arranged in a straight line, evidently following the course of a sensory nerve. A diagnosis of atypic herpes zoster seemed correct, and high frequency treatment was begun on May 8. On May 9 the patient said that following the treatment of yesterday she was free from pain for some hours. May 10 and 11 same treatment. No new area developed. May 14 patient came in agony from pain in the right shoulder and arm which had persisted all day, in spite of hot applications, etc. Felt much easier after treatment. The usual eruption had appeared on right arm and shoulder; not as much itching as usual. Five more treatments were given; no further return of pain."

Neuralgia.—Many observers have found lasting benefit in this class of cases from applications of the high fre-

quency currents. A lady who had been in India for some years, and had suffered much from Indian fever, was the subject of attacks of intense pain, mostly in the supra-orbital nerve. These attacks were especially frequent in damp, cold weather. After a course of twenty applications her pain had entirely ceased, the improvement being noticeable from the first. The method adopted was local application with a flat glass electrode, followed by ten to fifteen minutes' condensation, with massage over the seat of pain.

Dr. Somerville, in speaking of neuralgia, states:* "Although I cannot claim that in every case of neuralgia benefit has been permanent, yet temporary relief at any rate has been obtained. I may mention the case of a lady, about fifty-seven years of age, who suffered much pain along the course of the lower left intercostal nerves, extending well down the abdominal wall. Sedative liniments and massage had been tried without much beneficial effect. During August and September of 1902, while in the country, she was practically an invalid, and from being a lady of active habits she was compelled to keep her bed, as she became tired and exhausted on any slight exertion. The patient was very stout, and without the use of chloroform it was impossible to make a thorough examination of the abdomen; yet though her condition gave rise to an unpleasant suggestion of the presence of a neoplasm, nothing could be detected. This lady was treated by me in October, 1902, and after eighteen visits the pain entirely disappeared, and she was

* *Medical Electrology and Radiology*, May, 1904.

able to resume all her active habits. Sorrow, bereavement, and overstrain caused the neuralgia to return in the spring of 1903. Again the high frequency currents were resorted to, and pain was dispelled. She kept remarkably well all the summer, but has been compelled to return for further treatment during last month. Already, after a few visits, the pain has again almost entirely left her."

Chorea.—Dr. Gamlen, in the *Archives of the Roentgen Ray*, January, 1906, writes: "My experience in the treatment of chorea by high frequency currents has been limited to one case. It would, however, have been a good indication of the results to be derived therefrom had medicinal treatment not been given. At the same time, from the fact that arsenic had been taken with regularity for the period of a year before coming under my treatment, one would be inclined to believe that the primary benefit was derived from the high frequency treatment. From this single case I do not bring forward any conclusions.

"W. G., aged eight years, had suffered from chorea and obesity for four years, the results of an attack of rheumatic fever, and had received constant medical supervision during that time, the greater part of which he was taking arsenic in the form of Fowler's solution, without any improvement in the obesity and chorea.

"He came under my care in December, 1902, suffering from choreiform movements of the head, arms, and legs.

"Although below the normal height, his weight was $8\frac{1}{2}$ stones.

"High frequency sittings three times per week until

forty had been reached were given, and Fowler's solution, increasing until the daily dose reached 35 drops, was taken with the utmost regularity. At the end of this time his weight had decreased 2 stones, and all signs of the chorea had disappeared. At the end of four months there is no indication of return."

Dr. Somerville speaks highly of the effects of the currents on chorea.

Torticollis.—Dr. A. W. Crane, in the *Journal of Advanced Therapeutics* for September, 1905, relates a case of a young man who consulted him about his neck, his head being drawn stiffly to one side by an acute torticollis. The high frequency current was applied through a glass electrode, the effect of the treatment being immediate, the patient being able to leave wholly relieved. There was no return and no second application.

Hysteria, Neurasthenia, etc.—Dr. Gamlen, in a report of the utility of the high frequency currents, states :* "From my experience of over thirty cases of hysteria, neurasthenia, etc., I am convinced that most affections of the nervous system—and particularly those of a functional nature—are influenced in a surprising manner by the application of high frequency currents. Cases of hysteria—especially when accompanied by debility—receive benefit, but when no other ailment is existing most improvement results from suggestion.

"Having been told that improvement will be derived, the imagination is stimulated, and the cases are exceptional in which the impression formed from the wonderful

* *Archives of the Roentgen Ray*, February, 1906.

display does not have the desired effect. In most cases I deepen this impression by bringing to their notice the full knowledge of their treatment, and in no instance have I known the treatment (even if unsuccessful in curing) to aggravate the symptoms.

"CASE I.—A. S., aged thirty-five. This patient had been under constant treatment for nine months, complaining of palpitation, flatulence and debility, the symptoms being much exaggerated when, upon trying to pass an examination for insurance, he was refused, and informed that he had 'smoker's heart.' He came under my treatment in October, 1903, when he was suffering from a palpitating abdominal aorta, the rate of which, at the time of examination, was 140 per minute. He had been impressed (before consulting me) that high frequency currents would greatly aid him. During the twenty minutes in which he waited for treatment his pulse-rate remained over 130, whilst within five minutes of commencing the treatment it had fallen below 100, and at the termination of the first sitting it had dropped to 84.

"Sittings were given him three times per week. At the beginning of each sitting his pulse was always over 100, and at the end was invariably found to have fallen in rate. Twenty-four applications sufficed to banish the palpitation, the frequent pulse-rate had disappeared, and he was able to follow his usual employment. Though over four months have elapsed since cessation of treatment, he has had no further inconvenience from any of the before-mentioned symptoms.

"*August*, 1905.—Patient still in best of health.

"CASE II.—Miss T., aged nineteen years. After an attack of influenza in June, 1903, the patient entirely lost the use of her voice, and was treated medicinally to restore same for several months, but no improvement resulted. She consulted me on February 1, 1904, for this loss of speech. High frequency sittings of fifteen minutes' duration were given on thirty consecutive days, at the end of which the patient could speak in a monotonous whisper sufficiently loud to be heard at a distance of 3 feet. After twenty further sittings no more advance was made. The general treatment was then discarded, and local applications to the inside and outside of the throat from the resonator through the medium of a vacuum-tube electrode took their place. These were given daily, a smart reaction being purposely caused. Each application was made stronger, and great improvement resulted, the voice at times becoming quite natural. Finally, two applications to the inside of the larynx with a suitable glass electrode, and a suggestion that complete recovery would ensue, resulted in a permanent cure. There has been no return of the aphonia up to the present date (July, 1904).

"*August*, 1905.—No return of the aphonia.

"*Nervous Debility*—CASE III.—E. T., female, aged twenty-six, complained of sleeplessness, loss of appetite, loss of flesh, and general debility, pointing to a general nervous breakdown. Previous treatment for this condition had been only partially beneficial. The insomnia was latterly the most urgent symptom, and, after coming under the writer's observation without benefit by ordinary

treatment for this condition, he resorted to high frequency currents. For some time prior to this form of treatment the patient herself had been using opiates to produce sleep. The high frequency currents were given twice daily, and as it was noticed that on several occasions the patient fell asleep on the condensation couch during the administrations, prolonged sittings were given before her usual bedtime, with the result that after three weeks' trial of this method she obtained natural sleep. The desire for opiates, which had been gradually undermining her will-power, was thus overcome, and within a few weeks of her obtaining this natural sleep her appetite and general normal condition returned so far as to enable her to resume her daily avocations. Prior to this satisfactory result everything pointed to the patient becoming a hopeless victim to opiates.

"*August*, 1905.—Patient is still in the best of health.

"*Debility and Anæmia*—CASE IV.—Miss G., aged thirty-one, complained of symptoms pointing to debility, anæmia, and a condition of the system simulating slight attacks of Reynaud's disease. Her hair had within a short period turned grayish, thin, and harsh, and the scalp dry and scaly. With a view to stimulating a healthy condition of the hair, she had the option of having it cut close or submitting to a course of high frequency currents, the latter of which she chose. High frequency was administered irregularly during a period of three months, after which time the patient's general health was much improved, and the hair, which was growing freely, had assumed a more healthy lustre and was darker in colour, whilst the scalp had lost its scurfiness and looked quite natural."

CHAPTER VI.

DISEASES OF THE RESPIRATORY SYSTEM.

Catarrh.—In chronic laryngeal and pharyngeal catarrh the applications of the effluve, either from the brush electrode or from glass electrodes, to the outside of the neck and throat, and also to the nose when the mucous membrane of the nasal passages is affected, will clear up cases which for a long time may have been treated with gargles, sprays, and the like. A useful adjunct is the condensation method, at the same time drawing off discharges by gentle local massage.

An attack of acute catarrh of the nose and air-passages, "cold in the head," may often be arrested by a small glass electrode being put gently inside the nose, and the effluve taken from the top of a resonator so tuned that it may give a very soft and mild discharge.

Asthma.—It may be well imagined that high frequency currents would be of service in the treatment of this malady, and this has been found to be the case. Dr. Somerville writes:* "I am able to quote a sustained and apparently permanent cure of asthma as a result of high frequency treatment.

* *Medical Electrology and Radiology*, May, 1904.

"In September, 1902, I treated a clergyman who had suffered over a period of years from frequent attacks of asthma, especially on Monday mornings after the strain of Sunday work. The asthma was evidently neurotic in origin; it never troubled him while on holiday. With the exception of a short period, when his nervous system was depressed owing to an attack of influenza, he has been quite free from asthma, though it is eighteen months since treatment was begun. I may add, however, that, by way of prevention, he occasionally on a Sunday evening comes for a fifteen-minute sitting on the condensation couch.

"At my request this gentleman has sent me the following note:

"'One of the many inquiries put to me, if I speak of the treatment, is as to the durability of its effects. To that my reply has been that where the evil dealt with is evanescent in itself or recurrent in its cause, as in the case of my weariness after a long day's work, its effect passes and needs to be renewed; but that where the evil is permament or more deeply fixed in the system, as in the case of my bronchitic asthma, a regular course of treatment produces permanent result—at least, so I have found, for though even a simple treatment was a preventative or sedative, I have had no recurrence of my miserable experiences, except in connection with influenza, for eighteen months, even during the winter life of a hard-wrought City minister.'"

The following is the experience of Dr. Gamlen:* "In

* *Archives of the Roentgen Ray*, January, 1906.

two cases of asthma I gave both local and general applications from the high frequency apparatus, in addition to medicinal treatment. It was noteworthy that as soon as the high frequency sittings were commenced substantial improvement took place. The patients increased in weight, and gained much genuine ease. There was no doubt that the stimulation by the electrical currents materially decreased the attacks of dyspnœa."

Chronic Bronchitis.—In connection with this subject Dr. W. S. Hedley writes:* "High frequency currents, applied in the form of the effluve, effectually subdue the cough and promote the oxygenation of the blood and tissue metabolism at the same time as they increase elimination. They not only promote general nutrition, but effectually combat the atonic dilatation which favours a recrudescence of acute catarrh on the least exposure.

"*Chronic Tracheo-Bronchitis.*—In the milder form of this affection Reus confines electrical treatment to condensation, reserving the effluve for cases in which moist sounds are audible or the cough very troublesome.

"Electrical treatment, by promoting oxidation and removal of waste products, soon exerts a beneficial effect upon the progress of the case. There is usually a general as well as a local symptomatic improvement. Susceptibility to contract colds on the least exposure decreases as treatment proceeds.

"The following case of Reus' clearly illustrates the

* *Medical Electrology and Radiology*, May, 1904.

relation of the disease to nutritive aberrations, and the technique to be adopted :

" A cabinet-maker, aged fifty-one years, suffering from what he called rheumatic gout, and also subject to transient attacks of bronchial catarrh and shortness of breath on exertion, and habitual cough.

" Electrical treatment commenced with a sitting of condensation lasting five minutes, followed by effluvation of the base of the left lung and enlarged joints. The duration of the sessions of condensation was gradually extended to fifteen minutes daily, with applications of the effluve for a further period of ten minutes.

" After twenty-four sittings the patient was discharged free from all respiratory trouble ; he could also eat, sleep, and digest well."

Bronchiectasis.—When high frequency currents are employed for alleviating this condition, there is a marked improvement in the general condition before much improvement in the local lesion, this being due to there being so much local destruction. Dr. Gamlen records the following in the *Archives of the Roentgen Ray* for January, 1906 :

" The writer's experience of the treatment of bronchiectasis by means of high frequency currents has only been limited ; yet in two cases the results were striking. General applications were given by the couch, and after a few days perceptible improvement resulted. For serious cases sittings twice a day would be the most effective and speedy. It is interesting to observe how the currents effect an improvement. The sputum slowly but surely

increases, and becomes easier to discharge ; then, losing its thick and objectionable character, it develops a somewhat muco-purulent appearance. Finally, this condition improves to such an extent as merely to resemble ordinary bronchitic secretion. After a number of sittings a sample of sputum should be taken, a thorough examination of which will show that the patient has materially progressed. The inspection of sputum should be continued from time to time, and the improvement noted and recorded. The adoption of this system will undoubtedly encourage the practitioner to persevere until a complete cure has been effected, and my own experience certainly shows that this result cannot be regarded as unattainable. In dealing with this disease I have used high frequency currents as an isolated form of treatment, the patients not being even placed on any restricted diet.

"P. B., aged fifty-one, gave a history of several weeks' excessive drinking and previous alcoholic excesses. He had suffered from pneumonia of the right lung, from which he recovered after three weeks' treatment. Next he had a severe attack of bronchitis, with constant coughing and a large amount of bronchial discharge. This continued for eight weeks, during which time the discharge materially increased. One medical attendant diagnosed the case as phthisis, a second considered it to be chronic bronchitis, whilst a third was of opinion that it was bronchiectasis. On September 4, 1902, when the patient came under the writer's treatment, the condition was as follows: Quick, feeble pulse, subnormal temperature, with acute dyspnœa and sickly yellow appearance of

complexion. Examination of base of right lung revealed indications of a cavity—viz., amphoric breathing, râles, and loud bronchophony. The patient yielded a daily quantity of over a pint of exceptionally dirty malodorous sputum. At this juncture the case was diagnosed as putrid bronchitis, or gangrene of a portion of the lung. Stimulating treatment was given, and also large doses of creosote and carbolic acid.

"Turpentine inhalations were used for three weeks, at the end of which time there was not the slightest improvement, with the exception that the sputum was slightly less in quantity than formerly. The temperature had become typhoidal in character.

"High frequency sittings were next tried. Under the influence of the electrical currents, which were given twice a day, a temperature was recorded in the morning generally of about 100° to 101° F., and, as a rule, this increased to 103° or 104° F. It was noticed that the treatment always elevated the temperature at least 1°. After a few weeks' treatment, however, an improvement in this respect was effected. The morning temperature was now reduced to 99° F., and in the evening 101° to 101·4° F. was registered. Ten days' further treatment established a substantial advance. The patient was able to expectorate with greater ease, and the sputum became thinner, also losing much of its offensiveness.

"This standard of improvement was consistently maintained. After five weeks' treatment the sputum decreased to an unexpected extent, and the foul odour entirely disappeared. The temperature also became normal, and the

patient not only gained in weight and appetite, but also improved in appearance. Treatment was relinquished at the end of eleven weeks, during which time high frequency currents only had been administered, without the aid of medicine. The patient gained 42 pounds in weight. It is impossible to give any accurate idea of the lung condition, as careful examination was impossible owing to the foul smell emitted.

"*August*, 1905.—Patient still in good health."

CHAPTER VII.

DISEASES OF THE ALIMENTARY SYSTEM.

Chronic Dyspepsia.—In cases of this description the high frequency currents will undoubtedly be found to be of great benefit. The patient should lie on the couch, and the large electrode placed over the epigastrium and connected with the top of the resonator. This should be continued for ten minutes, after which the condensation method should be applied, the abdomen being at the same time massaged for ten minutes.

Dilatation of the Stomach.—In atonic dilatation of the stomach much benefit may be derived from the same method of treatment as that for dyspepsia.

Chronic Constipation.—In this condition reliance may be placed in effecting a permanent cure by means of the high frequency currents combined with abdominal massage. During condensation the abdomen should be well massaged, special attention being given to the colon.

Dr. Gamlen mentions the following case:* "E. R., aged fifty-four, had been under medical treatment two years suffering from obesity, indigestion, and severe constipation, the results varying, but no permanent benefit being derived. In January, 1903, he consulted me for

* *Archives of the Roentgen Ray*, February, 1906.

constant indigestion, great abdominal distension, and chronic constipation, a period of ten days frequently elapsing between the movements of the bowels. For a period of six weeks I gave him medicine for indigestion and constipation. He derived a little benefit during treatment, but on cessation symptoms reappeared.

"Medicine was then discontinued, with the exception of a daily dose of cascara sagrada, and high frequency sittings three times a week substituted.

"After a month's treatment his condition was greatly improved. Most of the indigestion and flatulence had disappeared, but the constipation, though greatly improved, was still distressing. The treatment was persevered with, together with massage applied to the abdomen for twenty minutes from a mechanical vibrator, deep pressure being given.

"At the termination of two months' further treatment, all indigestion, flatulence, and constipation, in addition to a large amount of the abdominal obesity, had disappeared.

"Three months afterwards there was a slight return of the symptoms, which, however, were speedily removed by medicine. Since that time the patient, though not in perfect health, is able to do without medicine."

Intestinal Colic.—In relation to this condition Dr. George Herschell remarks:* "In several cases of intestinal colic of obscure origin I have seen the most beneficial results follow the applications of high frequency electricity.

"Captain T. was sent to me by Dr. Kingscote on July 26, 1902. He had been operated on for appendicitis

* *Medical Electrology and Radiology*, June, 1904.

by Marmaduke Shield in May, 1900, who described the case in a letter to me as one of the worst cases of septic peritonitis which he had ever seen. Since the operation the patient had suffered from attacks of abdominal colic of a very severe nature, in many ways closely resembling cholelithiasis.

"These attacks were supposed to be due to adhesions. At the wish of the patient, without, I must confess, much expectation of doing him good, I commenced the daily application of high frequency currents. From the commencement of the treatment the attacks ceased, and he remained free from them until November 14 in the same year, when he came to me suffering from acute pain. This pain, which was of some hours' duration, disappeared during the application of the effluve from the resonator. The patient took a course of three weeks, and to my knowledge has remained free from attacks to the present date.

"In this case it is evident from the effect of the treatment that the diagnosis of adhesions could not be maintained, as it is difficult to imagine any form of electricity having so marked an effect upon them. The duration of the first course of treatment was six weeks, and the application used was the local application to the abdomen of the effluve from one end of the D'Arsonval coil of high tension. The patient during the application reclined upon the condensation couch, the metal plate of which was attached to the other end of the coil."

Colitis.—In the *Archives of the Roentgen Ray* for August, 1905, Mr. Edward W. H. Shenton writes: "A very valuable use of high frequency currents, and one to which

attention has not hitherto been drawn, is their beneficial effect in colitis, both of the mucous and ulcerative variety.

"Four years ago one was consulted on the advisability of X-ray treatment in an obstinate case of ulcerative colitis. It was agreed by those in charge of the case that the beneficial effects of the X rays, so noticeable in ulceration generally, warranted their application in this particular instance. One undertook the treatment, however, with no sanguine hopes of success, on account of the impossibility of the rays having effect through such a depth of intervening tissue. About a month of almost daily exposure of the abdomen to weak X rays produced no effect. The patient had been troubled for over a year with the complaint, and at this time was passing blood and mucus. There was chronic diarrhœa, he having to get up invariably eight times during the night. His general health suffered considerably, and he was incapacitated for work.

"As a forlorn hope, therefore, one suggested high frequency treatment, hoping that the benefit to the general health which so constantly attends the administration of these currents would indirectly affect the disease. After the first few applications, given on the condensation couch through the hands for ten minutes, followed by fifteen minutes' local application, sometimes from the low tension, sometimes from the resonator, there was a marked change in the patient, but not in his colitis symptoms. Being encouraged by this result, it was decided to settle down to a prolonged course of treatment, the patient attending on alternate days.

"For a fortnight or so his general health improved steadily; his appetite came back, and he slept well, except for the nocturnal interruptions mentioned above. Next followed a gradual cessation of the symptoms. The diarrhœa was less, the blood was less, as well as the pain.

"Each week would see him called up less often in the night, until a morning came on which he said he had passed the previous night undisturbed. The progress was sure, although somewhat slow, it being about nine months before he was completely well.

"Up to the present time he has had no return of his symptoms. He leads an active life in the City, and is only moderately careful of his diet.

"This case naturally encouraged one to try others, and in all eight were subjected to treatment within a few months of the first case. The mucous and ulcerative were equally divided, there being four of each. The following rough analysis of these eight cases is instructive:

	Duration of Treatment.	Result.
ULCERATIVE:		
A.—Case described above	Nine months.	Complete cure.
B.—Woman, aged 48 ...	Six months.	Symptoms markedly relieved.
C.—Man, aged 50 ...	„	No improvement.
D.—Woman, aged 40 ...	Six weeks.	Slight relief.
MUCOUS:		
E.—Woman, aged 30 ...	Three months.	Complete cure.
F.—Man, aged 48 ...	Six weeks.	„
G.—Man, aged 35 ...	„	„
H.—Man, aged 25 ...	„	Greatly improved.

Dr. Somerville remarks:* "Mucous colitis is a condition which is usually persistent in character, yet here, too, I have found high frequency currents to produce excellent and lasting results. I have treated several cases, all, with one exception, having been benefited. One case I may specially refer to. A lady of over forty was sent to me with the history that for twenty years she had been annoyed with mucous stools. Under high frequency treatment the excretion of mucous ceased, and there has been no return, though the case was dealt with sixteen months ago."

Appendix Sinus.—Dr. Alfred Sykes reports a cure, in from five to six weeks, of an intractable sinus left after an operation for appendicitis. The usual surgical remedies had been tried without result for many months. The form of electricity was the effluve applied by glass and other electrodes, which varied as the sinus improved.

Hæmorrhoids, Anal Fissure, Pruritus Ani.—In the *Lancet* of July 2, 1904, Mr. F. J. Bokenham gives an interesting summary of the results he had obtained during the past two and a half years. The author inclines, in the treatment of these affections, to the use of high-vacuum glass electrodes, which, when excited, give out an abundant supply of X rays. With metal electrodes he employs a current of 450 to 500 milliampères, with glass electrodes one of 100 to 150 milliampères. The duration of each session seldom exceeds fifteen minutes, five minutes being the average. The following is a summary of the results in tabular form:

* *Medical Electrology and Radiology*, May, 1904.

Nature of Complaint.	No. of Cases.	No. of Applications.	Results.				Remarks.
			Cured.	Greatly relieved.	Improved.	Failures.	
A.—Simple fissure	13	5 to 6	13	—	—	—	Prompt relief of anal spasm.
B.—Acute capillary piles ...	25	4 to 11	14	9	—	2	—
C.—Recurrent cases of extero-internal piles without marked hypertrophic changes	31	9 to 18	6	20	5	—	Improvement was almost immediate, and the associated constipation was at the same time relieved.
D.—Chronic cases with indurated folds, but without marked venous congestion ...	12	7 to 15	—	6	6	—	—
E.—Large venous external and internal piles ...	16	12 to 30	—	—	7	9	Two post-operative cases, the others old-standing cases complicated by chronic gastro-intestinal disorders.
F.—Post-partum piles (partial prolapsus recti)	6	8 to 19	4	2	—	—	—
G.—Pruritus ani with moist eczema of the parts	15	4 to 7	15	—	—	—	—

CHAPTER VIII.

DISEASES OF SPECIAL ORGANS.

THE EYE.—In cases of trachoma much good can be effected by high frequency currents. The method of application is condensation, during which the closed lids are gently massaged with the tips of the fingers for five minutes. Following this a glass electrode should be applied to each eye in succession for five minutes. Cases even of long standing will rapidly assume a more healthy appearance, and in course of time a cure may be effected.

T. G., a baker, aged twenty-six, good family history with the exception of one brother, now aged thirty, who suffered from granular lids for three years when he was twenty-three years of age. The patient had trachoma for six years, and had attended regularly for treatment at a hospital for nearly four years without any marked benefit. High frequency treatment was commenced in the manner described; unfortunately, the patient could not attend more often than once a week, but, nevertheless, considerable improvement was apparent after six to eight applications, and after six months recovery was practically complete. No other method of treatment was followed during this time.

Opacity (Ulceration) of Cornea.—J. S., a little girl, aged six, had suffered from corneal ulceration with thickened white opacities for over nine months, during which time she had been treated regularly at a hospital. High frequency treatment was then commenced by applying the glass electrode to the closed eyelids for five minutes to each eye. A marked improvement was soon noticed, and within six weeks vision was greatly improved; at the end of three months the cornea showed a slightly ground-glass appearance instead of the dense opacities formerly present. During the last few weeks of treatment the patient could open her eyelids under the electrode without any discomfort.

The Ear.—In cases of chronic catarrh of the middle ear, consequent upon an extension of chronic catarrhal inflammation of the naso-pharyngeal space, creeping up the Eustachian tubes, high frequency currents will be found of value. A small glass electrode should be held in the external auditory canal for five minutes in each ear consecutively, after which should follow condensation combined with massage around the ears. This method will effect an improvement in the hearing if persisted in, but it should be understood that if the disease has existed a long time the duration of the treatment will also be long. These cases are tedious, and calculated to try the patience of both patient and operator, but in the end much good will have been done.

A lady who was so deaf that she intended to purchase an ear-trumpet, after twenty-six applications was able to go to public meetings and hear the speaker comfortably.

Mrs. W., aged forty, had suffered from extreme deafness for some six or eight years, brought on by chronic catarrh of the middle ear, with a thickened tympanum and fixity of the ossicles. The case was complicated, as there was a marked family history of hereditary deafness. Treatment was given daily by the application of the glass electrode to each ear for from five to seven minutes. At the end of five weeks the patient could hear comfortably any conversation across a table or in a room, and was so far recovered that she discontinued the treatment; the benefit has continued up to the present time.

Tinnitus.—The same method of treatment will relieve this condition, but in this case the massage during condensation should be extended over the forehead.

Dysmenorrhœa.—Dr. W. A. Crane reports the following case in the *Journal of Advanced Therapeutics* for September, 1905: "A case that I had operated upon for dysmenorrhœa by dilatation and curettage returned after four months of relief, and announced that her old pains had returned to some extent. In spite of verbal encouragement and *liquor sedans*, the trouble rapidly grew worse with each monthly period. The pains would begin shortly before the flow started and continue for three days. She refused to have the operation repeated. One evening the mother telephoned me that her daughter had begun her monthly suffering, and asked me to come up and give her something to relieve the pain. I asked her to bring her daughter down in a closed carriage, and I would see if a new form

of treatment would be of any avail. A vacuum tube was inserted so as to lie against the uterus, and fifteen minutes of the full current given. After ten minutes the patient declared that her pain had vanished. After the treatment she felt perfectly well, the weight and dragging in the pelvic viscera having disappeared.

"The pains did not return during that period. With great expectations of a permanent cure I gave her repeated treatments preceding the next period. But the pains began just as before. A single treatment, however, after the onset of the pains gave complete relief. Further observation fully convinced me that the pains could not be prevented by any treatment given before the onset of the periodic pains. I have had no opportunity of verifying these results in any other case."

Gleet, Vaginitis.—Dr. Gamlen reports the following cases:* "H. S., aged thirty-five years, had a history of three attacks of gonorrhœa extending over five years, and eventually leaving chronic gleet. Medicinal treatment had been applied on many occasions, but without success. When the patient came under my care, local applications by means of large metallic bougies were tried concurrent with medicinal treatment. After five weeks, however, the improvement was so slight that it became advisable to adopt other means.

"The bougie was connected with the terminal on the top of the resonator, and in this way the high frequency currents were administered. At the same time general applications of high frequency were given. After sixteen

* *Archives of the Roentgen Ray*, February, 1906.

of these combined applications the case was apparently cured.

"The local treatment of five minutes' duration was given every second day without discomfort to the patient. At first the discharge from the urethra increased, but after a few additional sittings it gradually diminished, and after the twelfth application finally disappeared.

"The fact that the currents had proved successful in the treatment of some skin diseases led the writer to assume that they would be effective in dealing with venereal manifestations of the mucous membranes. That reasoning was fully born out by results.

"A woman, aged twenty-three, with a history of gonorrhœa of three weeks' duration, had a large amount of vaginal and vulval discharge. The usual local applications having proved futile, high frequency treatment, both general and local, was resorted to, the affected parts being reached by means of a suitably shaped glass electrode. After the first few applications the irritation, and later the discharge, gradually subsided. Fourteen applications effected a complete cure."

CHAPTER IX.

DISEASES OF THE SKIN.

Dr. Gamlen reports good results in the treatment of prurigo, varicose ulcers, chronic eczema, and psoriasis, with the effluve from the brush or from glass electrodes. He also recommends general treatment by condensation to improve the general health. As regards lupus erythematosus, Dr. Gamlen prefers to rely on X rays rather than high frequency currents.

Dr. Somerville, in speaking of the treatment of diseases of the skin by high frequency currents, states: "In reference to the influence of the high frequency currents in certain skin affections, I may mention the case of a lady about fifty-five years of age who suffered from psoriasis, which was present in large patches over the hips, lower limbs, and chest. The disease had been present for more than ten years, yet at the time it yielded remarkably to treatment, and she remained scarcely affected by the eruption till the date of her death from malignant disease, about six months after treatment was discontinued.

"Another case of psoriasis of the lower extremities, but of a much milder type, was treated by me in October, 1903.

I was much surprised at the time to note how quickly the scaly patches disappeared, till not a vestige remained. I had occasion to see this patient last month, when on examination I failed to detect any signs of the eruption.

"I have just now under treatment two cases of psoriasis. In one, where the eruption has been for years all over the scalp, and where also a few small spots occurred on other parts of the body, the disease is yielding remarkably well to treatment, to the delight and surprise alike of the patient herself, her husband, who is a doctor, and the medical friend who sent her to me.

"On the other hand, I may mention that I have under my care at present a gentleman who has suffered from a gouty psoriasis for fifteen years, where, so far as I can judge, no appreciable benefit has taken place, though he has visited me over fifty times. The high frequency currents are therefore, like other methods of treatment, not infallible."

In the *Archives of the Roentgen Ray* for July, 1904, Dr. Margaret M. Sharpe writes:

"*Chilblains.*—In February of this year (1904) a patient was sent to me with disfiguring scars on her face and hand, the result of an accident with a pane of glass. While the treatment was in progress bad chilblains came on the injured hand, one actually involving the area of injury. The chilblains disappeared after five minutes' treatment with high frequency currents.

"*Congestion of the face* in a patient who was under treatment by the X rays for a malignant growth on the

nose. The congestion yielded rapidly to the high frequency application.

"*Nævus.*—A baby, eight months old, was sent to me in May of this year for advice as to the desirability of operating on a nævus. The nævus was entirely subcutaneous—on the back between the angle of the right scapula and the spine. It was about the size of a florin and the thickness of two. The skin was not discoloured, but the mother said that sometimes 'it seemed to swell and get blue.' I wished, if possible, to avoid a painful operation, so I tried a similar treatment to that which had proved so effective in the two previous cases. The result was entirely satisfactory after seven applications of five to eight minutes' duration.

"I used in all three cases a vacuum electrode of my own designing. It is exhausted to a much higher degree than those usually made for use with the high frequency current. It gives a bright green fluorescence even in daylight, gives off no sparks or perceptible brush discharge, does not heat, and imparts no sensation whatever to the skin, which does not redden. It is held in contact with the skin, and in the case of the nævus some pressure was used."

In other kinds of skin diseases the application of high frequency currents will be found useful. It is recommended to benefit the general health by condensation in addition to local applications.

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THE END.

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